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Anatomy of Hemlock Ring Shake Associated with Sapsucker Injury

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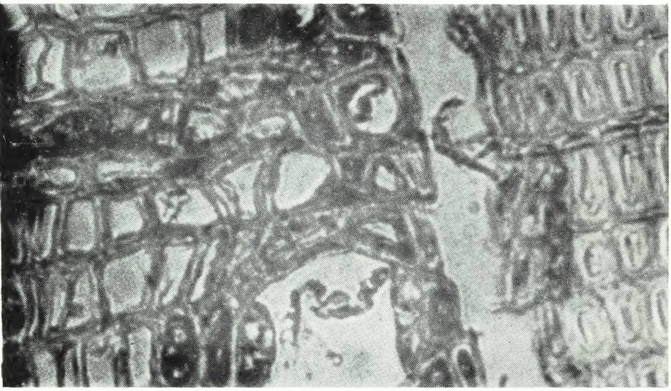

by Richard N. Jorgensen
and Sophie L. Lecznar

U. S. FOREST SERVICE RESEARCH PAPER NE-21
1964

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

Anatomy of Hemlock Ring Shake Associated with Sapsucker Injury

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The Authors

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A New Look at Shake

SHAKE — a defect of standing trees in which the wood separates along the grain, the greater part between and parallel to the growth rings — has long been considered uncontrollable. It is a serious defect. The utilization of some species — such as hemlock, which is especially susceptible to shake — is severely limited by the frequent occurrence of this defect.

Various theories have been advanced in attempts to explain shake. Koehler (1933), as a result of wood-technology studies at the U. S. Forest Products Laboratory, suggested three probable causes of internal stresses in trees, which may contribute to the formation of ring shakes: (1) greater circumferential growth than radial growth; (2) reduction in turgidity of the older tissues; and (3) chemical shrinkage of the older wood.

He emphasized that the presence of parenchyma cells in the tree stem would be most effective in setting up such stresses. These cells remain alive and turgid for years after they are formed, and become well embedded in the wood before they die and lose their turgidity. As they die, he postulated, tension stresses would be set up in the heartwood, and this would throw the sapwood, which still has turgid cells, into compression.

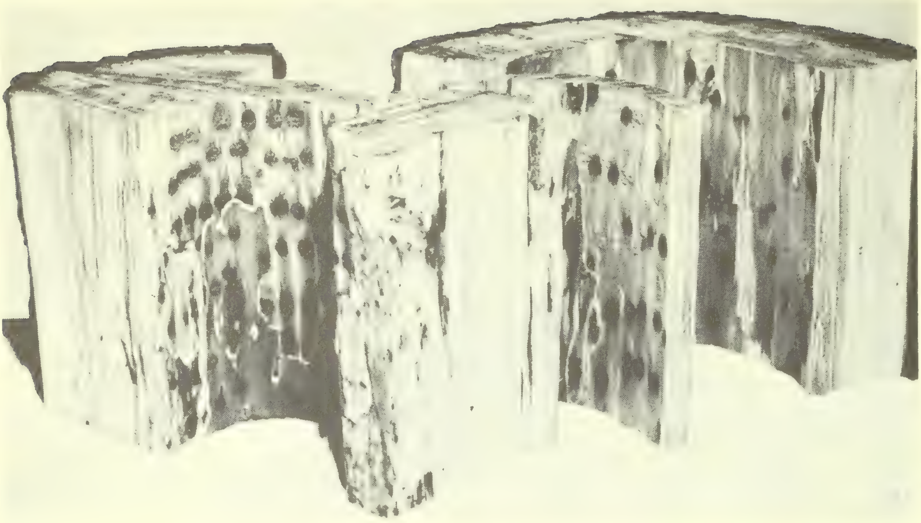


Figure 1. — **This section from a hemlock tree pulled apart along several ring-shake cracks. The scars from old sapsucker wounds line the separated surfaces. (From Shigo 1963.)**

Mergen (1958) postulated that the formation of compression wood in the flexible leaders of hemlock trees results eventually in the formation of shake because of the variations in strength and shrinkage properties of this reaction wood.

A number of other explanations have been offered (Wilson 1962), but none has gained wide acceptance. Shake has been attributed to weather conditions, especially wind; but research on the subject indicates that these theories probably are not correct.

In some of the research on the subject, shake has been related to age of the tree. Wilson reported that ring shake in eastern hemlock is statistically related to tree age: he found that shakes were formed between the ages of 60 and 125 years. The relationship was not influenced by the diameter of the tree nor by site.

Recent work by Shigo (1963) in New England has drawn attention to a new aspect of shake: he found a 100-percent correlation between occurrence of ring shake in eastern hemlock and damage caused by the feeding activities of the yellow-bellied sapsucker (*Sphyrapicus varius varius* L.), a bird of the woodpecker order. In dissecting trees in the course of forest-disease studies, Shigo found that shake invariably occurred in zones of old injuries caused by sapsuckers (fig. 1). He found a similar association between shake and sapsucker damage in some hardwoods.

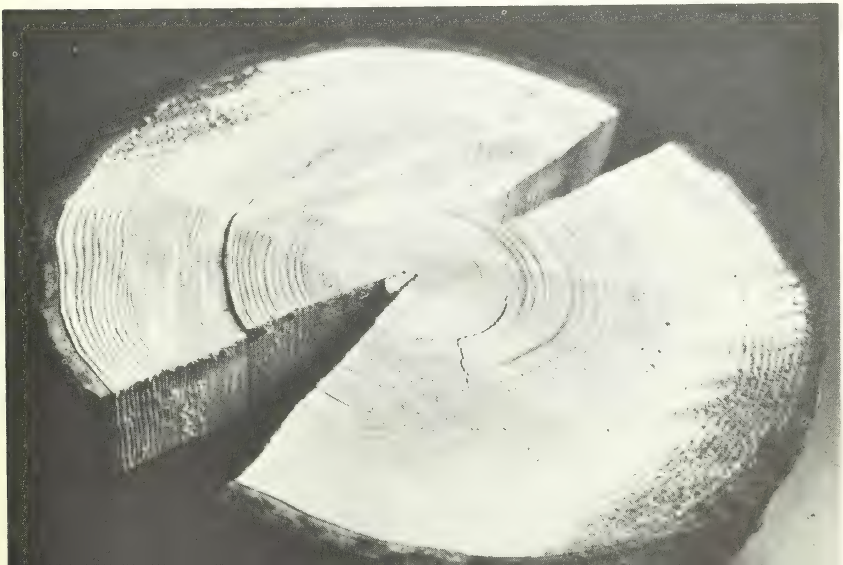
In the light of these findings, the anatomy of shake areas associated with sapsucker damage was investigated in an effort to obtain further information about the causes of shake defects.

Procedure

Eight eastern hemlock trees (*Tsuga canadensis* L. Carr.) growing in the Bartlett Experimental Forest at Bartlett, New Hampshire, were selected for study. These trees, ranging in diameter breast high from 8 to 19 inches, were selected because the bark showed evidence of old sapsucker attack.

The trees were felled in May 1963. After felling, each tree was cut through at the area of sapsucker attack, and a 2-inch-thick

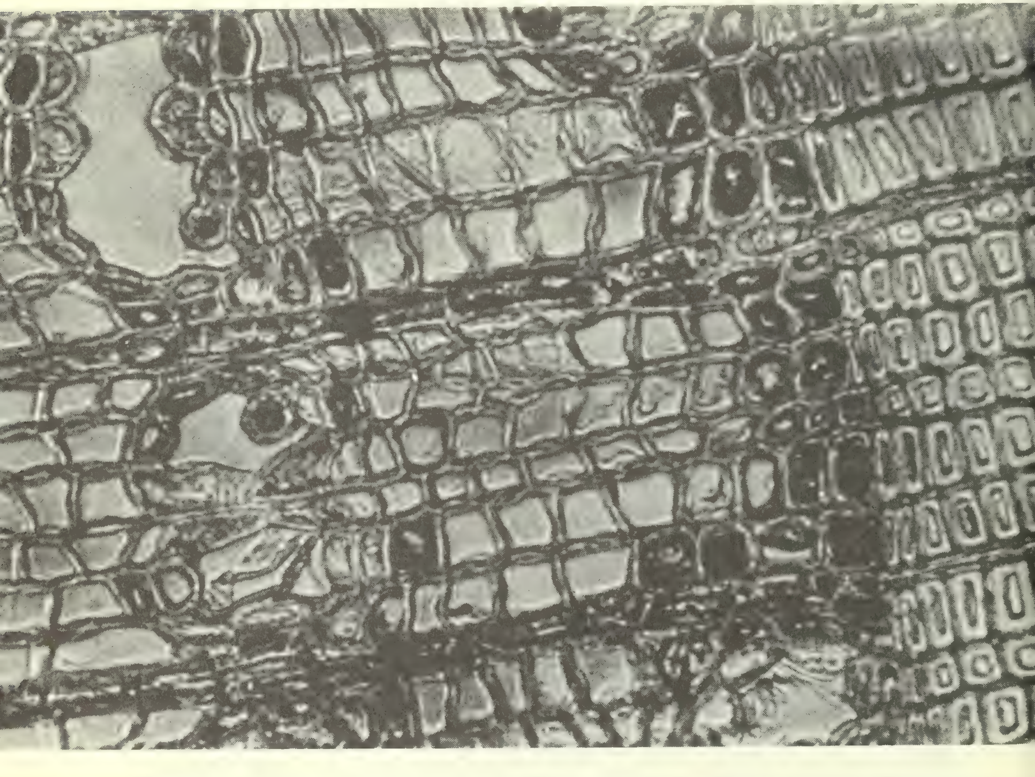
Figure 2. — Cross-section of one of the sample trees. Wedges have been cut out to obtain samples of the shake zone for study.



disk was removed for examination. Each tree was found to contain some shake and to have the sapsucker damage in conjunction with it as described by Shigo.

Two additional disks were taken from the injured area of each tree and were taken to the Forestry School of The Pennsylvania State University for laboratory study. In the laboratory each disk was sectioned radially with a saw to obtain a wedge-shaped piece containing the shake and sapsucker damage (fig. 2). A small block was cut from the damage zone and mounted in celloidin, and a microtome was used to cut both radial and tangential sections 11 microns thick. These unstained sections, mounted on slides, were used for microscopic study.

Figure 3. — Sapsucker-damaged area, in cross-section at 100X. Latewood cells are at right, parenchyma cells at right center. Resin canals are at left center.



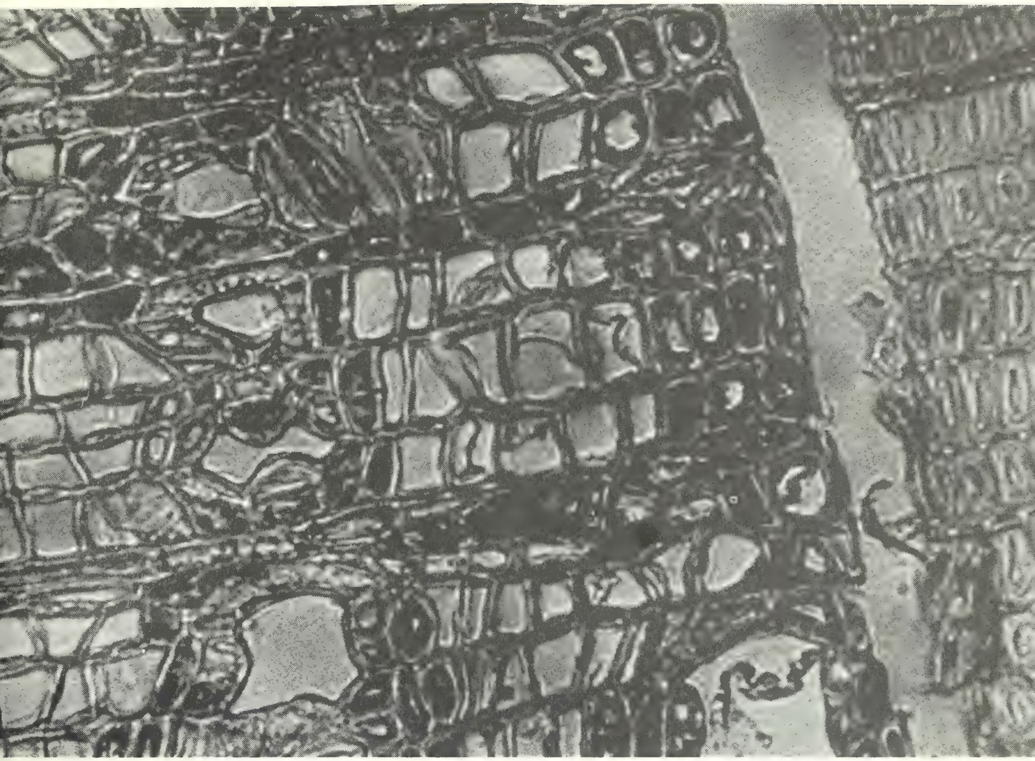


Figure 4. — Shake at sapsucker-damaged area, in cross-section at 100X. Middle lamella separation and torn cell separation are evident.

Results

Earlywood parenchyma and traumatic resin canals (fig. 3) were found to occur at the point of sapsucker injury in all eight trees. Where the shake occurred, it was between the latewood cells and traumatic parenchyma (fig. 4 and fig. 5). The sapsucker damage shown in the photographs was done approximately 70 years ago.

The schizogenous traumatic resin canals observed, and the traumatic parenchyma in isolated spots in the springwood, are characteristic of wound formations. The large masses of cells (fig. 5) — irregular in size, shape, and arrangement, and with no strands as seen radially — identify wound parenchyma. The

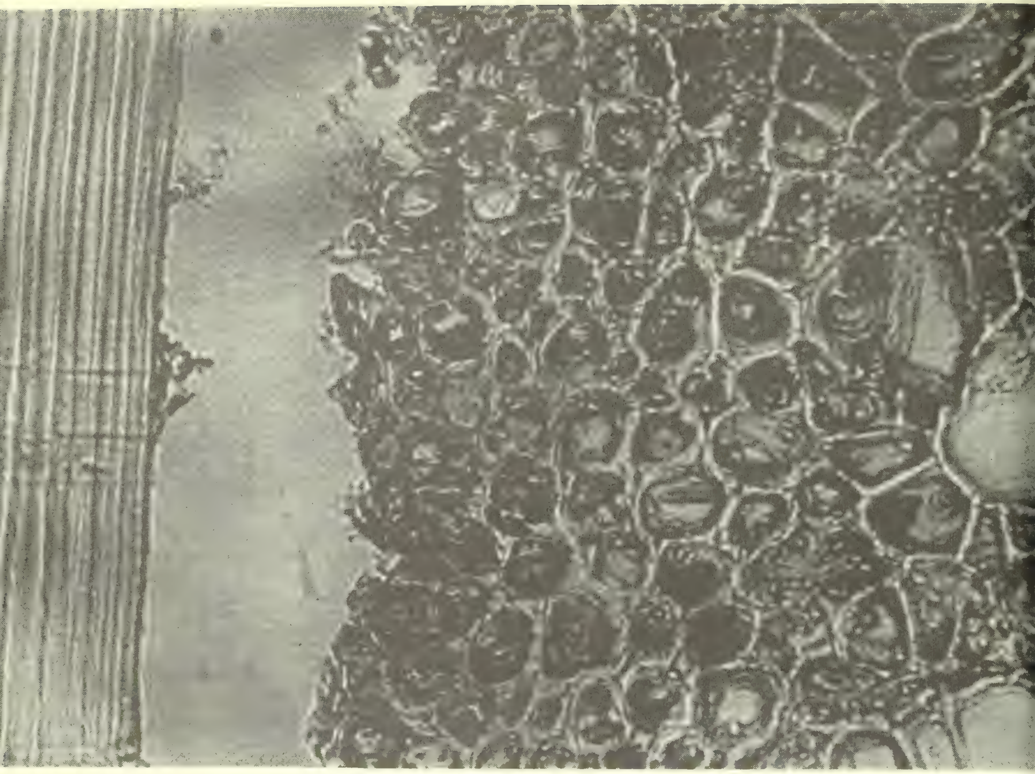


Figure 5. — Traumatic parenchyma at shake. Radial section at 100X.

cell walls are rather thick and abundantly pitted, and the cell contents are dark in color.

The shake found was a cell-wall type of failure in which the first row of springwood tracheids was torn across the cell wall from lumen to lumen, or a separation at the compound middle lamella (figures 4, 5, and 6). Separations at the middle lamella predominated. This form of ring shake is similar to two types of shelling failures in softwoods described by Kutsche and Ethington (1962).

In all the microtome sections studied, the traumatic parenchyma and resin canals appeared only in the early springwood. There was no evidence of parenchyma or resin canals in the later parts of any growth rings.

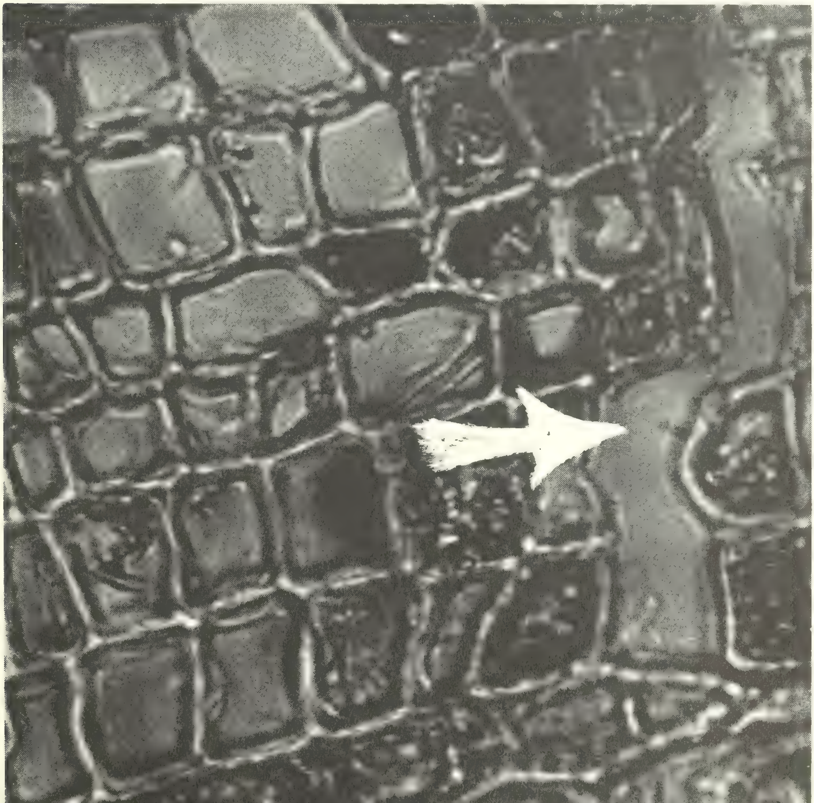
Conclusions and Discussion

Laboratory study of the wood structure in the eight sample trees lends support to several theories and findings concerning shake. The formation of large amounts of traumatic parenchyma and traumatic resin canals at the site of sapsucker injury is typical of conifer wound tissue.

The cell structure of the wood in the areas of sapsucker damage tends to support the theory advanced by Koehler: that the dehydration of the parenchyma cells produces internal stresses that contribute to formation of shake defects.

No data are available on the life of the traumatic parenchyma in eastern hemlock, but the parenchyma will certainly die and dehydrate as the trees reach advanced age. This supports the findings of Wilson: that shakes do not form in hemlock until the trees reach an age of at least 60 years.

Figure 6. — Shake (arrow) at damaged area, showing a middle lamella separation. Cross-section at 450X.



Resin canals are not normal to hemlock, and if present are caused by injury. Thompson and Sifton (1925) showed that wounds caused rows of canals in more or less close tangential series and that scattered canals were numerous at short distances from the wound. Record (1934) reported that resin ducts originate in the cambial zone in response to a special stimulus or irritation, in this case physical damage by the sapsuckers.

The presence of a single row of traumatic canals in each ring of the trees studied is not easily explained. From the cellular evidence of the samples observed it must be concluded that, in the year when the ring was formed, these trees were subject to a single sapsucker attack that occurred during a limited time in the early growing season. In one tree, this early-season attack was sufficient to produce external scars that were visible after 70 years.

The feeding habits of the sapsuckers can be related to the cellular evidence found. Beal and McAtee (1922) have described the springtime sampling done by the sapsuckers in selecting certain "orchard" trees for heavy feeding later in the season. Such sampling would account for the single row of resin canals in the springwood areas of the sectioned trees.

It must be concluded that the springtime sampling of the sapsuckers produces scars visible on the bark of hemlock many years later. Continued attack during the entire growing season would undoubtedly result in large areas of killed cambium and scar overgrowth as noted by Shigo (1963) on some trees. Control of damage to hemlock as an effort to reduce the occurrence of shake would undoubtedly be difficult. If such control were attempted it ought to be directed not only at the intense feeding on orchard trees, but also against the springtime exploratory attacks.

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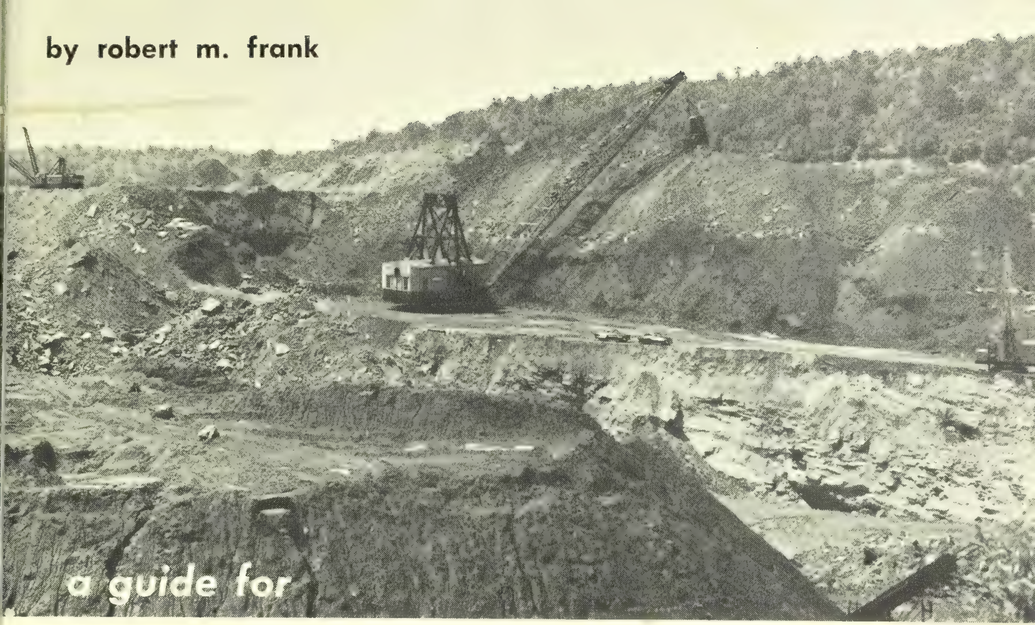
by robert m. frank



a guide for SCREEN AND COVER PLANTING of trees on anthracite mine-spoil areas

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1964

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

PREFACE

THIS is the first of several reports dealing with mine-spoil revegetation research in the Anthracite Region of Pennsylvania. The second report will deal with survival and early growth of the older forest plantings made in compliance with the original anthracite strip-mine law of 1948. A third report will describe the early results from experimental plantings established in 1963 on various spoil materials. Other studies relating to forestry problems in the Anthracite Region are in the planning stage.

In the study upon which this report is based, 41 unit-area maps were prepared, along with supporting tables that give detailed planting-site information, by communities, for the entire region. Though all this information is not included in this report, it is available in limited quantities upon request from the Pennsylvania Power and Light Company, Allentown, Pa., and from the Northeastern Forest Experiment Station, Upper Darby, Pa.

The Pennsylvania Power and Light Company, whose interest led to initiation of this project on anthracite mine-spoil revegetation in 1961, has financed most of this study as well as the other above-mentioned studies in the present research program.

COVER PHOTO. Strip-mining in the Anthracite Region of eastern Pennsylvania creates unsightly landscapes that put the communities of the Region at a disadvantage in their attempts to attract new industries and their people. Here huge earth-moving machines dig away the overburden to get at the coal seams lying near the surface.

a guide for

SCREEN AND COVER PLANTING

of trees on anthracite mine-spoil areas

THE AUTHOR . . .

ROBERT M. FRANK received his bachelor of science degree in forestry in 1954 from The Pennsylvania State University, and in 1956 he received from the same institution a master of forestry degree in forest products. After a year with a wholesale lumber concern, he joined the staff of the U. S. Forest Service's Northeastern Forest Experiment Station, Division of Forest Economics Research, Upper Darby, Pa. He served as a research forester at the Station's research unit at Kingston, Pa., where this manuscript was prepared. Since April 1963 the author has been serving at the Station's timber-management research project at Orono, Maine.

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INTRODUCTION

COMMUNITY development agencies, chambers of commerce, and others interested in industrial development are convinced that aesthetic beauty in a region increases its opportunities for economic growth. Aesthetic beauty, of course, is but one of many factors that influence industrial development and economic growth. Available labor, available industrial sites, low-cost financing, proximity to markets, and efficient transportation services are other important prerequisites. Enhancement of aesthetic features obviously cannot, by itself, transform an economically depressed region into one of flourishing communities. However, in the Anthracite Region of eastern Pennsylvania, the other prerequisites are, or can be, amply supplied; aesthetically attractive surroundings seem to be the main item that is lacking.

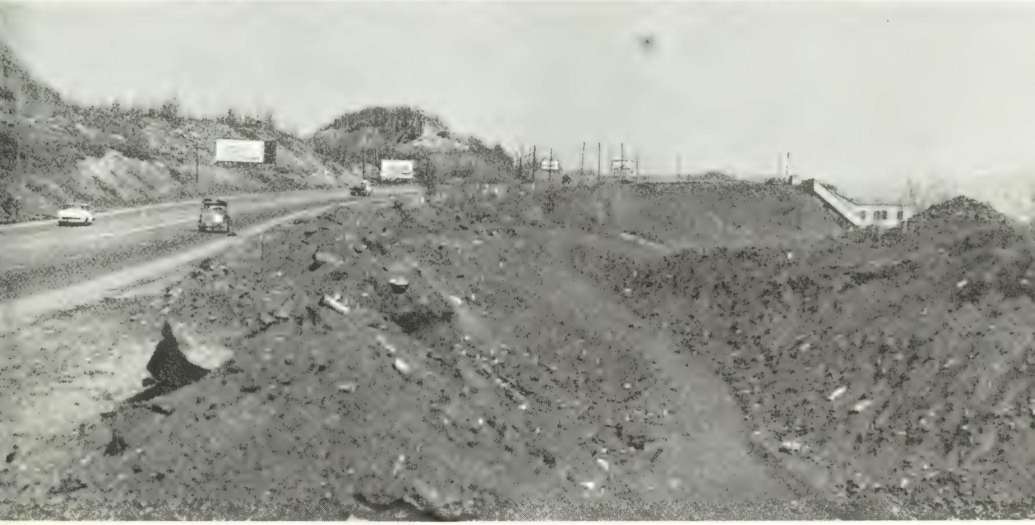

Figure 1.—Strip-mine spoils along the highways of the Anthracite Region give the traveler the impression that this is bleak, poor country.

This was not always so. At one time the valleys and hillsides and rivers and streams of the Region compared favorably with or surpassed other areas of the Northeast in natural beauty. But 140 years of coal mining have completely changed the picture. A substantial proportion of the land surface has been transformed — in many instances unavoidably — because coal cannot be mined by any method without depositing waste materials somewhere on the landscape; and it cannot be strip-mined without extensive disturbance of the land surface.

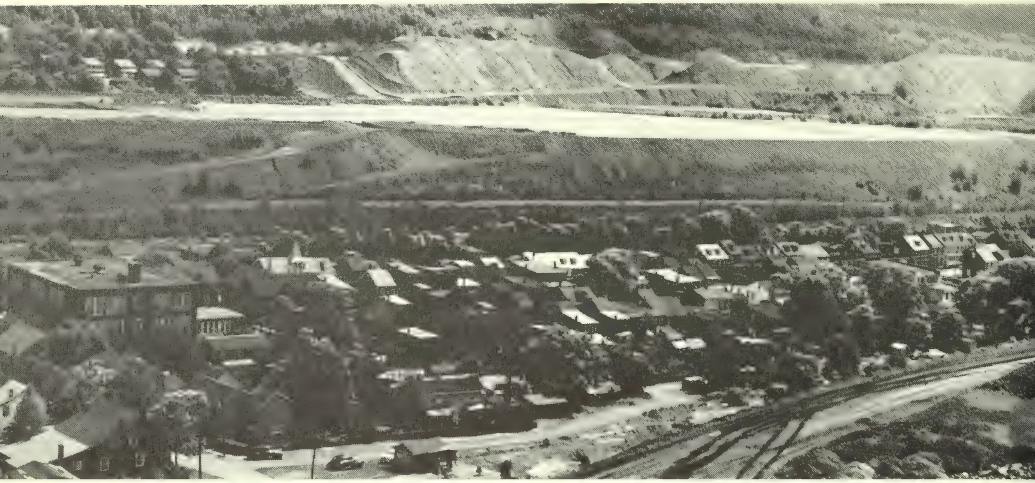

Figure 2. — The mine spoils are especially objectionable where they encroach upon the communities of the Region.

This transformation now is most widely evident in thousands of acres of ravaged hillsides — the open pits and spoil banks that have resulted from strip-mining (figs. 1 and 2). On a smaller scale, but perhaps more conspicuous, are the man-made mountains of deep-mine waste, most of which are located in or near centers of population (fig. 3).

Ideally, the way to eliminate the eyesores caused by strip-mining would be to restore the topography to its original contour. However, such restoration in many places would be difficult and expensive; furthermore, complete physical restoration would not be advisable for some strippings because, even though presently inactive, they may be worked again in the future. Physical restoration would be even more difficult and expensive for the piles of deep-mine waste that have no economic potential because about the only way to dispose of this material would be to put it back underground.

Obviously some other way for improving the appearance of the countryside must be sought. One practical answer is to establish vegetation — trees for the most part — either to cover the raw, disturbed areas and unsightly piles, or to shield them from view.

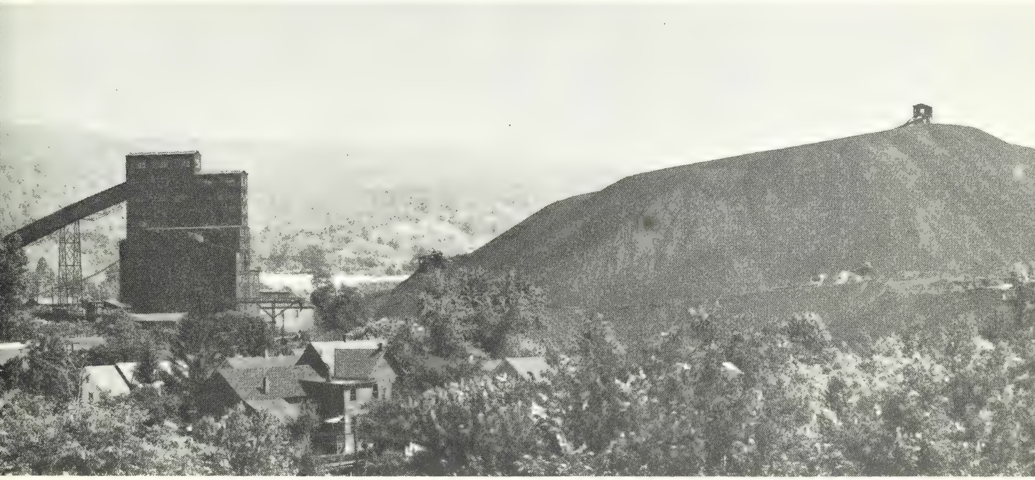

Figure 3. — Deep-mining operations leave man-made mountains of waste matter.

Except for some conflicting estimates of the amount of disturbed area in the coal fields, little information has been available as to how much of the area is unstocked or is poorly stocked and suitable for planting. And except for a small pilot study conducted in Schuylkill County in 1958[1], no information existed as to how much of the disturbed area would require planting to accomplish reasonable aesthetic objectives, precisely where the areas are in relation to highways and residential sections, and where the needs for planting for aesthetic purposes are most crucial.

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[1] Frank, Robert M., and Charles M. Clements. A FOREST SCREEN FOR SPOIL BANKS. U. S. Forest Serv. Northeast. Forest Expt. Sta., mimeographed report, 5 pp., 1958.

These were the questions that the Northeastern Forest Experiment Station of the U. S. Forest Service addressed itself to when it undertook its present research program in the revegetation of coal-mining spoils.

THE STUDY

In 1962 a survey was made, and a series of maps was prepared on which all land disturbed by coal mining in the entire Anthracite Region was delineated and classified according to spoil type, existing tree cover, and visibility from important communities and main roads. The maps show locations for establishing tree plantings to screen or cover[2] all disturbed areas that are conspicuously visible from highways and residential sections. Areas suitable for development as water-recreation sites also were noted. These sites could serve as oases for travelers desiring to picnic or perhaps to fish or swim. Local residents might enjoy ice-skating at such sites during the winter.

Thus this report, with its supplemental maps and related tabular data, can serve as a guide for individuals or organizations interested in area reforestation and beautification. If put into action, the recommendations offered here could contribute to the economic betterment of local communities by restoring attractive surroundings to a region that was once richly endowed with them.

This report is limited to a factual presentation of conditions as they now exist, and a suggested program of tree planting to improve the aesthetic aspects of the region. Other aspects that may need improvement are not considered. Problems of water pollution, soil erosion, and mine-waste disposal are not within the scope of the report, although they would certainly be involved in any comprehensive program of community betterment.

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[2] Throughout this report, the term *screen* or *screen planting* refers to narrow strips of trees so placed that, when they have attained 15 feet or more in height, they will shield or screen a disturbed area from view from a highway or residential section. *Cover* or *cover planting* refers to area-wide, plantation-type plantings; these are recommended where screen planting would not be effective.

Only samples of the detailed maps and tabular data are included in this report; the supplemental material is available to users upon request. The report as here presented without the supplemental material describes the situation and the recommended planting in general terms for the Region as a whole, and it explains the study methods and the kind of information provided for use in action programs.

THE REGION

The Anthracite Region may be defined loosely as that section of eastern Pennsylvania which contains deposits of anthracite or hard coal. This definition usually is understood to include the relatively small deposits of semi-anthracite coal found in Dauphin and Sullivan Counties.

The term Anthracite Region may be interpreted to mean only the areas underlain with coal; or it may mean those areas plus variously defined intervening and surrounding areas in which the economy has been strongly affected by the coal industry. So, it is necessary to define our usage of the term:

> *The term Anthracite Region as used in this report refers to the several disconnected areas from which coal has been mined, plus the surrounding undisturbed terrain from which mining disturbances are visible. This places the boundaries of each mining area usually on mountain ridges or at the near edge of forested areas.*

This survey was limited to the area defined above. It includes parts of 10 counties: Wayne, Susquehanna, Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Northumberland, Dauphin, and Lebanon.

Four great coal fields are recognized in the Region: Northern, Eastern-Middle, Western-Middle, and Southern (fig. 4). Together they cover about 480 square miles and include 8 cities. Five of the cities — Carbondale, Scranton, Pittston, Wilkes-Barre, and Nanticoke — are in the Northern Field. The other fields

The Coal Fields

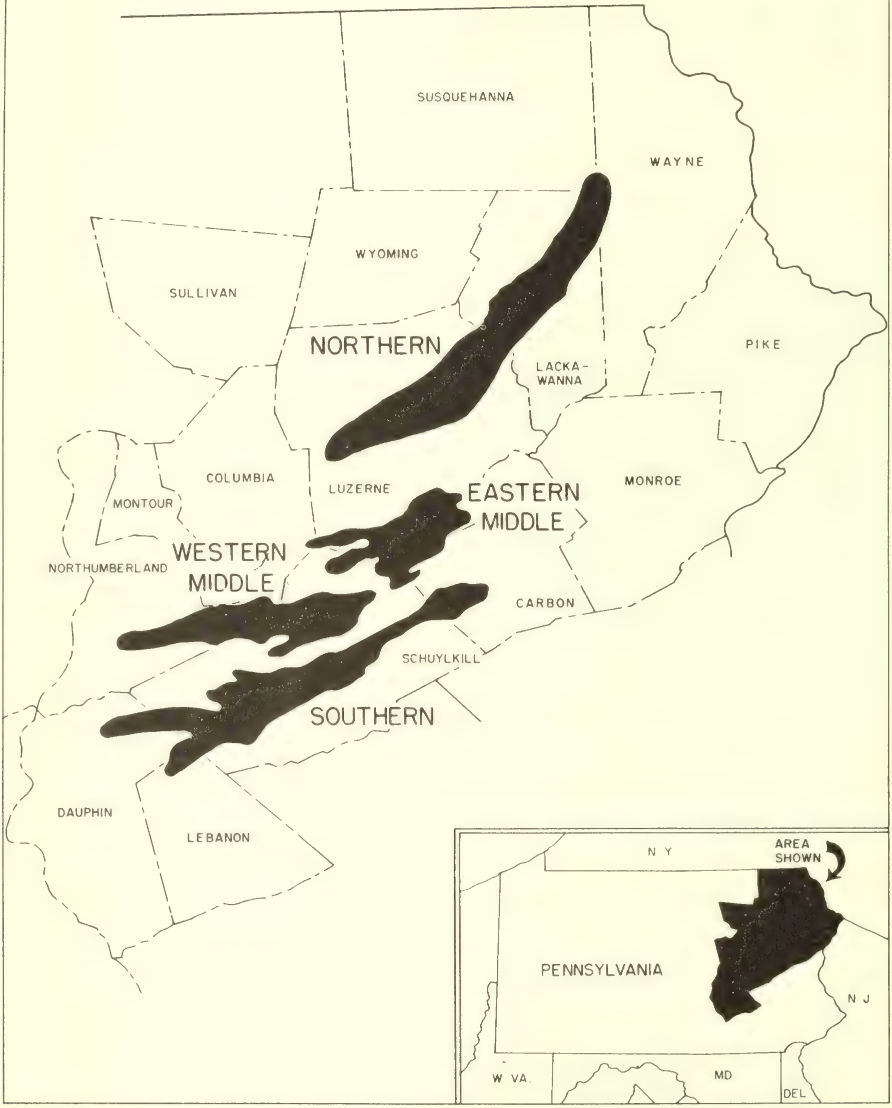


Figure 4. — The four major coal fields in the Anthracite Region of Pennsylvania.

contain one city each: Hazleton in the Eastern-Middle Field, Shamokin in the Western-Middle Field, and Pottsville in the Southern Field.

The total area mapped in the survey was 706 square miles. This includes the 480 square miles of coal fields and 226 square miles of surrounding terrain. The 706 square miles is the Anthracite Region in the sense used in this report.

METHODS

UNIT AREAS FOR MAPPING

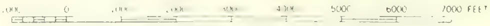
For mapping purposes, the Anthracite Region was divided into 41 segments or unit areas. The unit-area maps cover areas ranging from 1,383 acres to 27,368 acres. A city, borough, or other population center was selected as a hub in each unit area to facilitate administration of action programs on a local basis. Thirty-five unit areas have as a hub a community with a population exceeding 5,000. Four other hubs are boroughs ranging in population from slightly under 2,000 to just over 3,500. Trevorton, an unincorporated place of 2,600 population, and Rush Township, are designated as the hubs of the other two areas.

A unit area consists of: (1) a hub community; (2) the highway approaches to the community; and (3) all land within approximately one-half the distance to adjacent hub communities. All cities in the Anthracite Region and all boroughs in excess of 5,000 population were designated as hub communities. Many smaller boroughs and populated sections of townships, most of which are situated along the highway approaches to the hub communities, were included in the unit areas. Figure 5 is an example of a unit-area map. Tables supporting this map can be found in appendix I at the end of this report (tables 1 to 5).

PHOTO INTERPRETATION

Areas of surface disturbance resulting from all phases of coal mining, regardless of date of occurrence, were delineated on aerial photographs and were classified according to degree of

PITTSTON UNIT AREA



1962

▬	UNIT AREA BOUNDARY
═	INTERSTATE HIGHWAYS AND PENNA TURNPIKE
—	U S HIGHWAYS
– – –	PENNA HIGHWAYS
···········	OTHER IMPORTANT ROADS AND STREETS
▨	INDUSTRIAL, COMMERCIAL, AND RESIDENTIAL AREAS
▤	WATER
☐	AREA NOT EFFECTIVELY VISIBLE
▭	STRIPPING PITS AND BANKS AND INTERSPERSED UNDISTURBED AREAS
▩	CULM, CINDER, AND ASH PILES, ROCK DUMPS, COAL PROCESSING AREAS, SILT BASINS, AND STREAM SEDIMENTATION AREAS
▧	POTENTIAL FOREST COVER PLANTING SITES
∘∘∘∘∘∘∘∘∘∘∘	POTENTIAL FOREST SCREEN PLANTING SITES
19	SCREEN PLANTING SITE NUMBER
A	0 – 10 PERCENT TREE COVER
B	11 – 50 ·· ·· ··
C	51 – 100 ·· ·· ··
⑤	POTENTIAL WATER RECREATION SITES

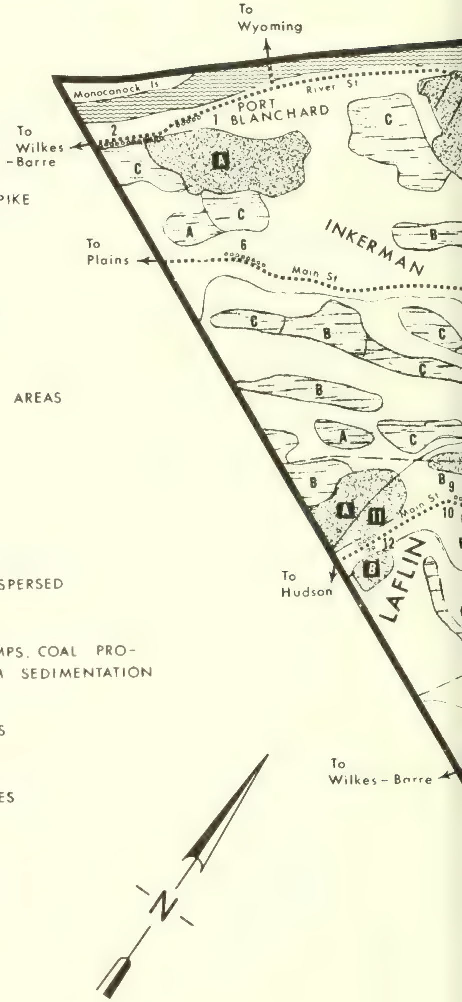
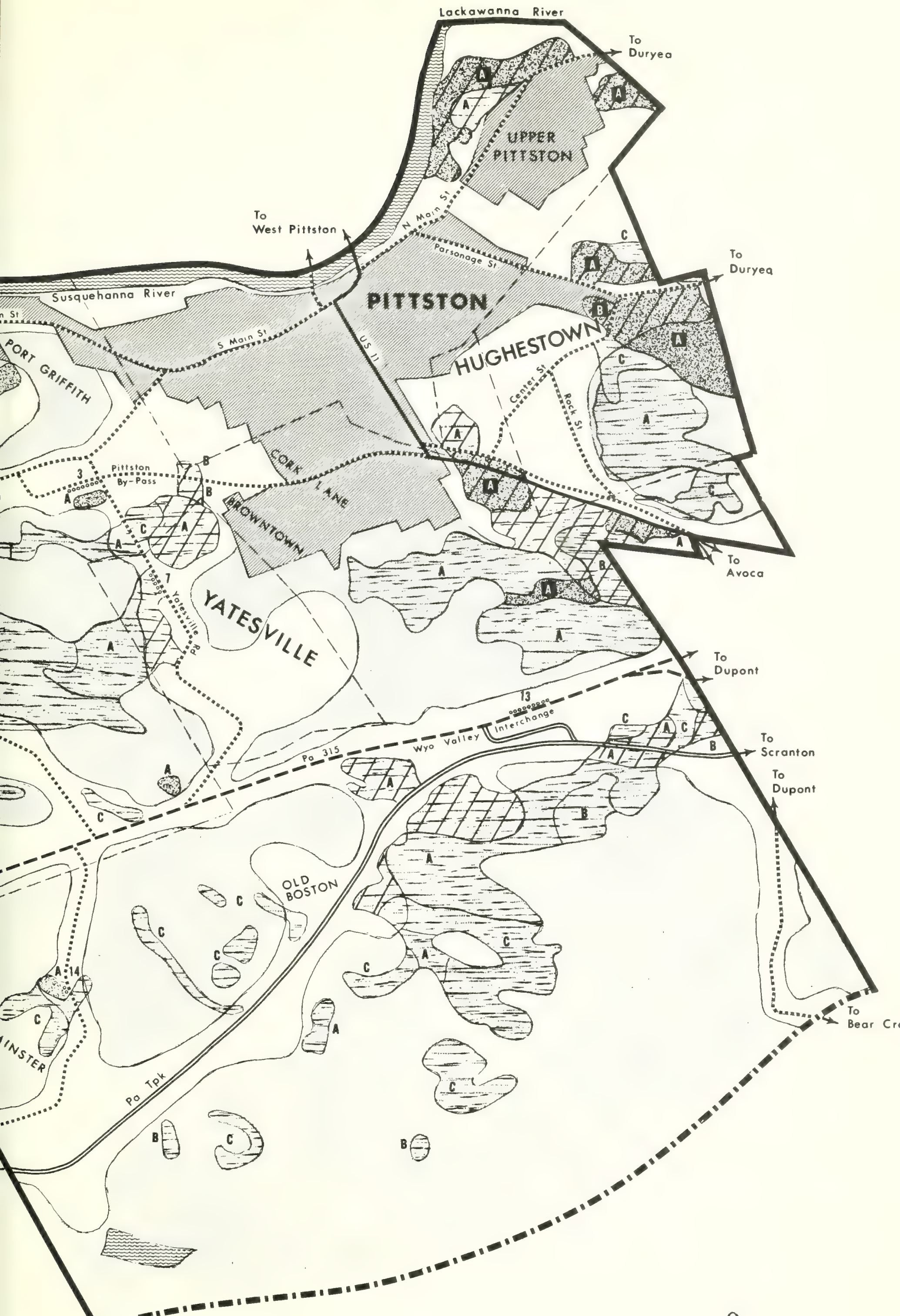


Figure 5. — A unit-area map. This is an example of the 41 unit-area maps prepared to delineate the tree-planting possibilities in the Anthracite Region.


Lackawanna River
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PORT GRIFFITH
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HUGHESTOWN
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CORK LANE
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Yatesville Rd
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tree cover and spoil type. A pocket stereoscope was used in this work. The photographs dated from 1958 to 1960. They were at an approximate scale of 1:20,000, which means that 3 inches of photo distance approximates 1 mile of ground distance.

A three-dimensional projection instrument known as a multiscope (fig. 6), which is a stereoscopic plotter, was next employed to transfer outlines of disturbed areas from the aerial photographs to U. S. Geological Survey quadrangle maps having a scale of 1:24,000. The transferred delineations on the quadrangles were then rechecked against the photographs by comparing the relative positions of disturbed areas and man-made features such as buildings and highway intersections. Upon completion of this step the photographs and quadrangles were ready for use in the field.

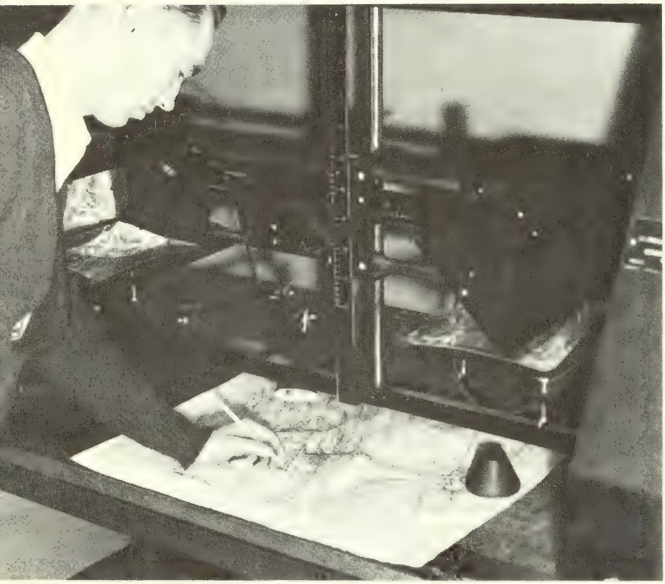


Figure 6.—Transferring features from a stereoscopic pair of aerial photographs to a U. S. Geological Survey map by use of a multiscope.

FIELD PROCEDURES

Areas that were manifestly visible from highways and major communities were checked against the delineations on the aerial photographs to verify the interpretations and to correct, as necessary, for changes in boundaries of disturbed areas and in density of tree cover that had occurred since the photographs were made. The checking and charting were done, for the most part, from an automobile at advantageous locations in the communities and along the highways.

Determining Limits of Visibility

To determine visibility limits, observations were made from more than one point. Along highways, the terrain on both sides was inspected from both directions of travel. Partial barriers to view, such as roadbed cuts, parallel rows of buildings, trees and other vegetation (fig. 7), if they effectively obscured the area behind, were delineated as the visibility limit. On the other hand, panoramas more than 1 mile away were considered as being not visible, since the condition of surface areas at that distance is not readily discernible.

However, within the boundaries of hub communities, all land within 1 mile from a road or built-up section was considered as visible area, even if some of it was in fact obscured. This was done because these areas seemed especially deserving of attention in any program concerned with community beautification. It resulted in a majority of the potential forest cover planting sites being located within borough and city limits.

Visibility limits within 1 mile of roads and hub communities were noted and mapped. Except within the boundaries of hub communities, the areas considered of highest priority for treatment and given primary attention in this report are areas referred to as *frontage.* Most of the frontage is highway frontage; it is the land within 2,000 feet on either side of a road. A small part of the total frontage consists of 2,000-foot-wide marginal bands along built-up sections of hub communities at places where there is no important road. For tabulation purposes, frontage was measured and recorded in miles. One mile of highway comprised 2 miles of frontage.

All the screen and cover planting sites that were selected and marked on the maps for early treatment lie either in the visible portions of the frontage areas or within the boundaries of hub

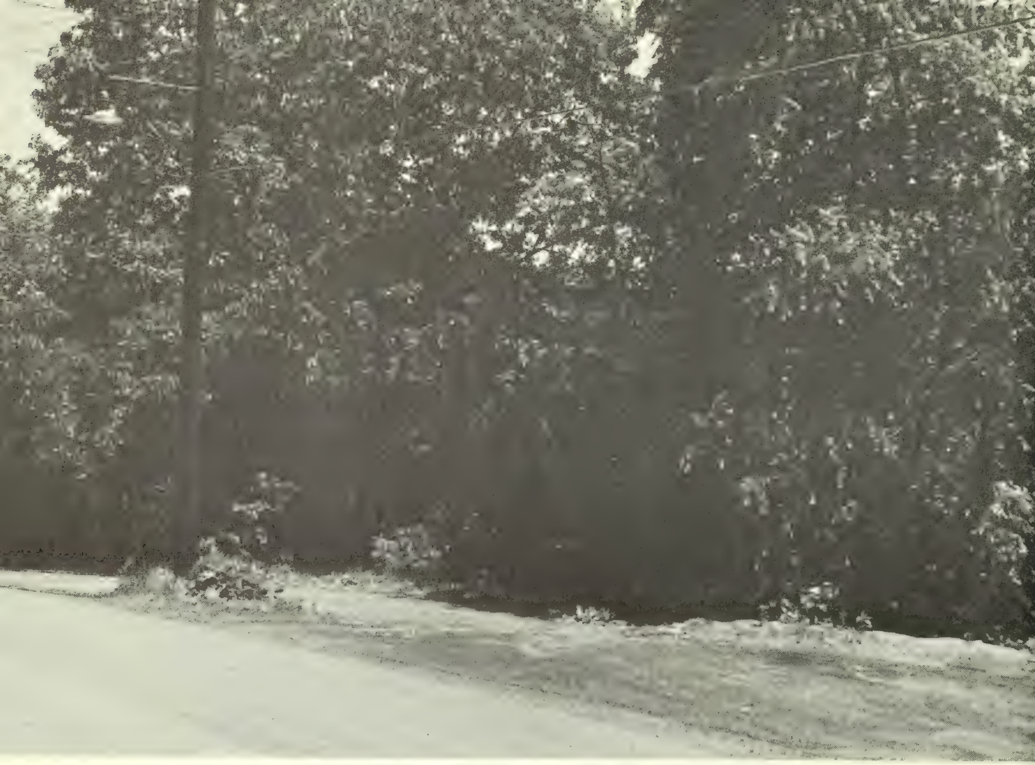
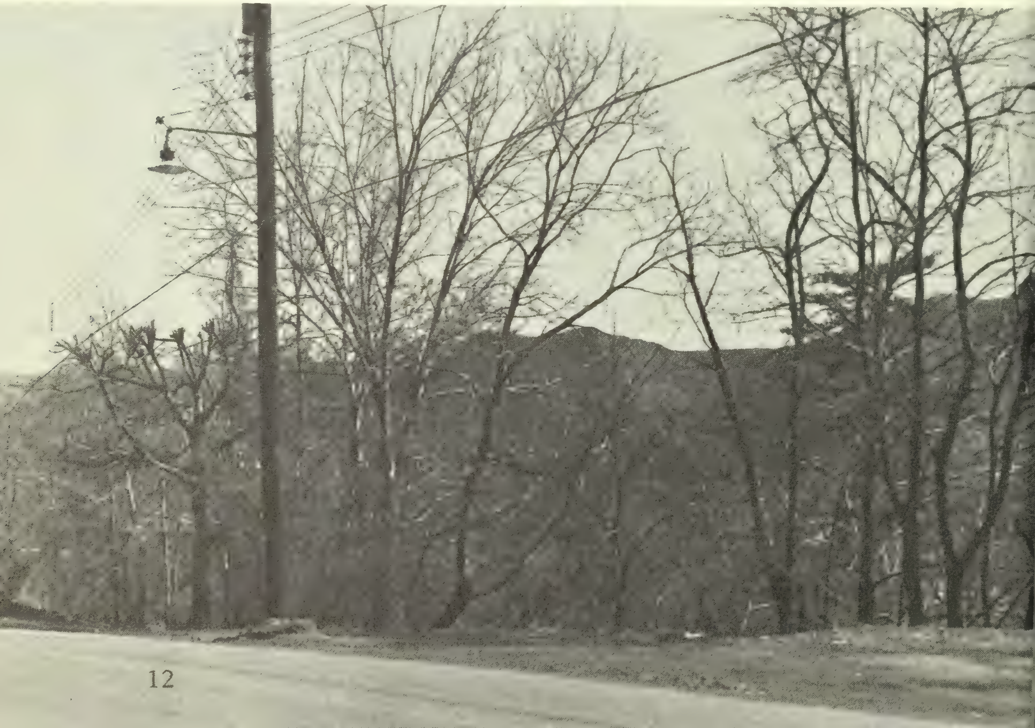


Figure 7.—A natural strip of hardwoods, 25 to 50 feet wide, effectively screens a large culm pile from a highway during the summer (above), but is inadequate during the winter (below).



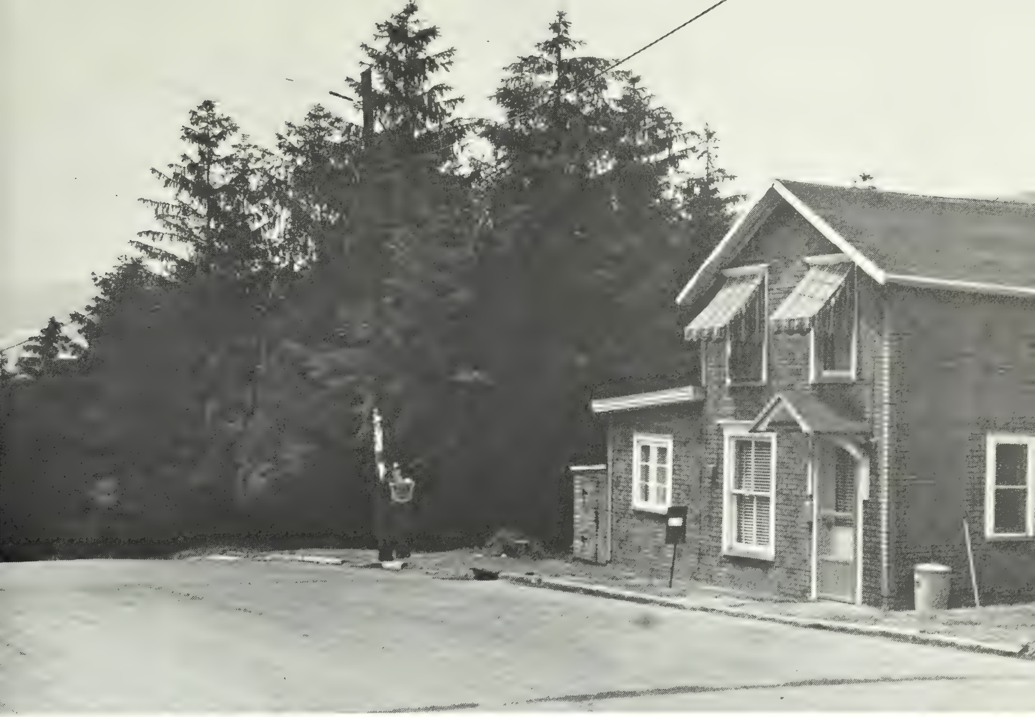
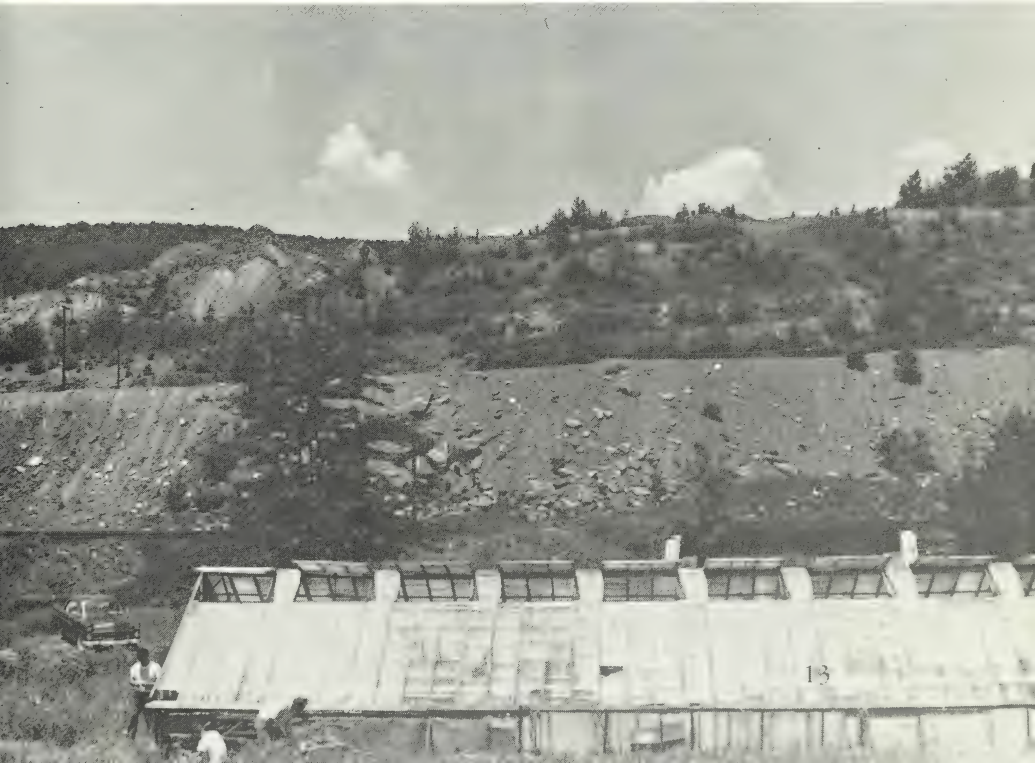


Figure 8.—Evergreen conifers provide effective screening at all seasons. From the roadside (above) you see this green screen of spruces. But just step through the screen of trees and you see the mine spoils (below).



communities. In the latter, cover plantings are recommended to a distance of 2,000 feet from built-up sections.

No attempt was made to indicate situations or conditions that might require some other treatment besides tree planting.

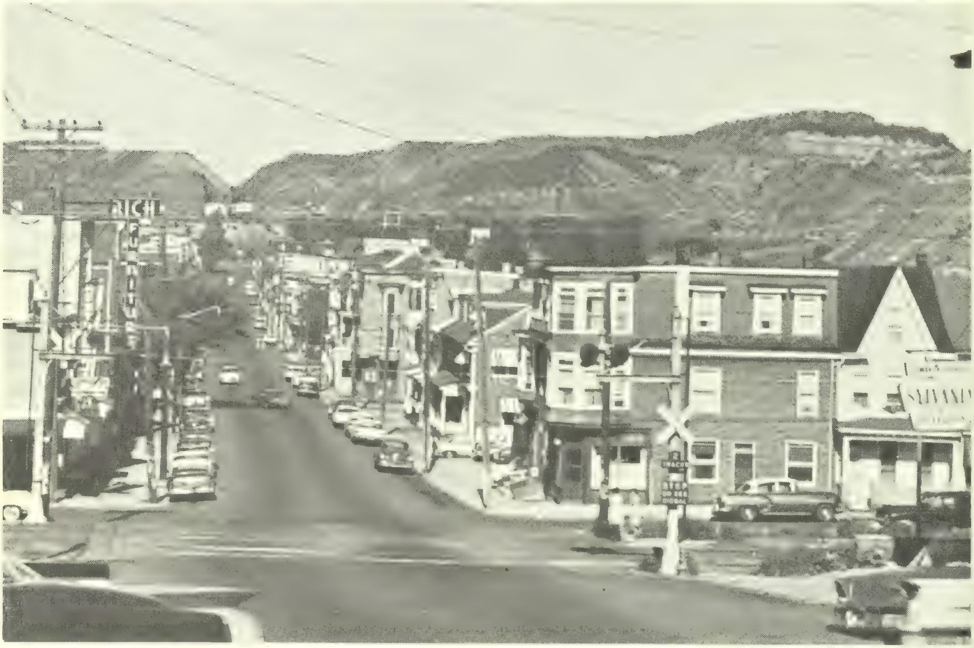


Figure 9. — Potential cover-planting sites. Above: the mountains of mine waste looming above this town could not be effectively shut off from view by a screen of trees; so a broad cover planting is recommended. Below: an earlier planting is already beginning to have effect on this cover-planting site along a highway.

Selecting and Classifying Potential Forest Screen Planting Sites

An area was designated as a potential site for a roadside screen planting if a strip of trees on the site would effectively screen a disturbed area from view (fig. 8). Current use of the site was not a selection factor except, if the land was being utilized for another purpose, screen width often was limited to 25 feet. Nor was capacity of the site to support tree growth a selection factor. However, the effects of different spoil types and conditions on tree growth were investigated in 1962 in another study, and the results are available for guidance in future planting programs.[3]

Sites were classified according to: (1) kind of spoil — whether strip-mine spoil or deep-mine waste; and (2) amount of tree cover — 0-10 percent or 11-50 percent. Spoils of either kind that were supporting more than 50 percent tree cover were considered to be adequately vegetated, and were not listed as planting sites.

Recommendations for site-preparation work were based more on aesthetic values than on considerations of tree survival. Two intensities of site preparation were recognized: (1) minor — involving only grading; and (2) major — involving both grading and backfilling. In some places major site preparation was recommended to create a site at least 25 feet wide.

To assure exact relocation later, the sites were witnessed; that is, their position was recorded in relation to specific nearby utility-line poles or other permanent objects.

Widths of planting sites were estimated by eye; lengths were scaled from aerial photographs, estimated by pacing, or calculated from odometer readings.

Selecting and Classifying Potential Forest Cover Planting Sites

Potential cover-planting sites (fig. 9) were designated wherever a screen of trees would not be fully effective. These sites were classified by kind of spoil and amount of tree cover in the same manner as the forest screen planting sites. Again, current use of the site and its ability to support tree growth were not selection factors. No site-preparation recommendations were made for these areas, and they were not tied into witness markers. General location was recorded, however, such as position in relation to a borough or to a prominent landmark.

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[3] Czapowskyj, Miroslaw M., and William E. McQuilkin. SURVIVAL AND EARLY GROWTH OF PLANTED FOREST TREES ON STRIP-MINE SPOILS IN THE ANTHRACITE REGION. U. S. Forest Serv. Northeast. Forest Expt. Sta., office report, 29 pp. 1963.

Selecting and Classifying Potential Water-Recreation Sites

Potential water-recreation sites on disturbed areas were usually selected within view of highways (fig. 10). The primary criterion for selection was water, either a surface stream or a situation where surface or subsurface drainage could be impounded. Bodies of water or potential bodies of water, such as stripping pits, had to be at least 1 acre in size to qualify for consideration.

Classification of these sites was by: (1) size classes — 1 to 5 acres, 6 to 10 acres, 11 to 20 acres, and more than 20 acres; and (2) site condition — pits containing water, dry pits, and stream channels. The water-recreation sites are listed in the supporting tables and are indicated on the unit-area maps.

PREPARING MAPS AND DETERMINING AREA STATISTICS

Upon completion of the field work, the features required on the unit-area maps were traced from the U.S.G.S. quadrangle maps. These tracings, at a scale of 1 inch equals 2,000 feet, were ultimately utilized for reproducing copies. County maps were made by first tracing the sections that did not appear on the unit-area maps, then inserting the unit-area maps in their proper places. Finally, each county assembly was reduced photographically to provide county maps at a scale of 1 inch equals 1 mile. From these county maps a regional map was constructed by tracing desired detail onto a new master sheet. This was then reduced photographically to a scale of 1 inch equals 4 miles.

Area measurements were taken directly from the completed unit-area master tracings. These area statistics were determined by use of dot grids having 36 dots per square inch. Two dot

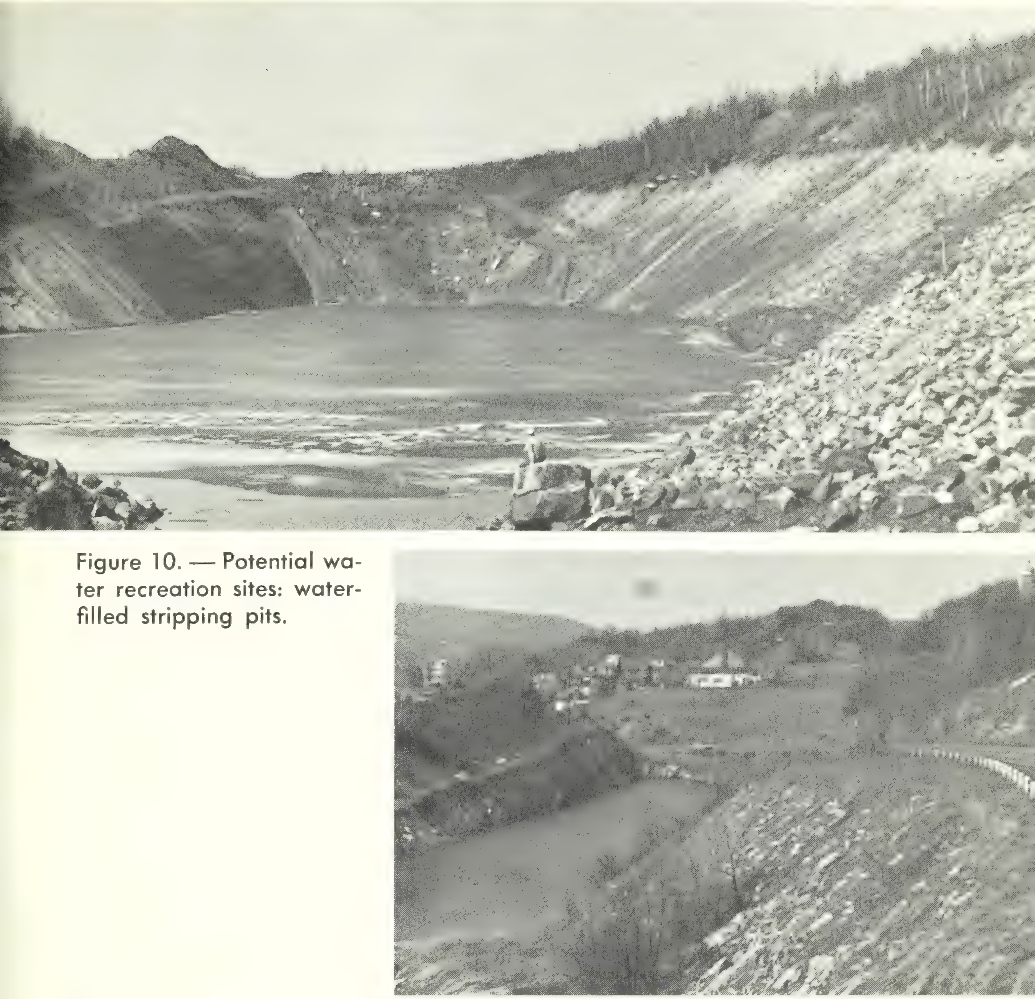


Figure 10. — Potential water recreation sites: water-filled stripping pits.

counts were averaged for calculating each area figure appearing in this report. Linear measurements of frontage were made with a map measurer. Two measurements were taken and averaged for the reported figures.

Because of differences in definitions of disturbed area or in procedures used to obtain the data, our area determinations are not strictly comparable with determinations from earlier surveys. These differences should be recognized in any attempts to compare area determinations for the purpose of estimating increases in disturbed land.

RESULTS AND DISCUSSION

The survey results are presented in a form intended to serve the needs of agencies and individuals who might use the data. Municipal governments and civic organizations should find the unit-area data useful. So might some county groups. However, other county groups may be more interested in data organized on a county basis. Information pertaining to the entire Anthracite Region may be helpful to state or federal agencies.

As indicated earlier, the voluminous data collected on potential planting sites and potential water-recreation sites, the summary tabulations of these data, and the unit-area and county maps, are not included in this report. All this material is available to civic and public officials or agencies, and to interested researchers, from the Pennsylvania Power and Light Company and the Northeastern Forest Experiment Station. In the pages to follow, the survey results and planting recommendations are presented and discussed in a rather general way for the Anthracite Region as a whole.

LAND AND COVER CLASSIFICATION

The classification data dealing with the amount and kind of disturbance, visibility of disturbed areas from highways and hub communities, and density of tree cover on the disturbed areas, are discussed first in reference to all disturbed land, and second in reference to those portions of the disturbed land that lie along highways and community borders — that is, the portions designated as frontage.

All-Area Classification

About 25 percent of the land surface in the Anthracite Region has been disturbed by coal-mining activities; this amounts to about 112,000 acres. By coal fields, the amount of disturbance varies from slightly less than 20 percent in the Northern Field to 35 percent in the Western-Middle Field. In general, visible and non-visible areas contain about the same proportions of disturbed land (fig. 11).

Figure 11.—The amount of area disturbed in the portions of each coal field that are visible from highways and developed sections of hub communities, and in the portions that are not visible — 1962.

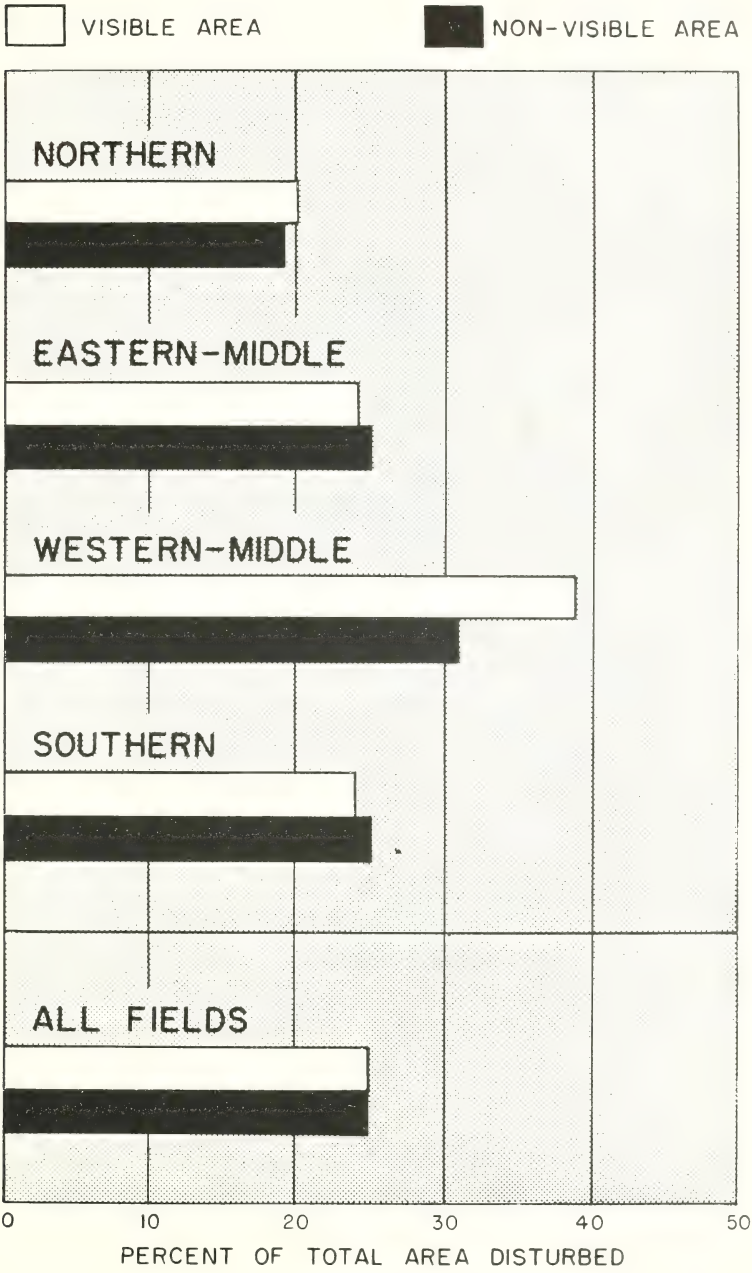
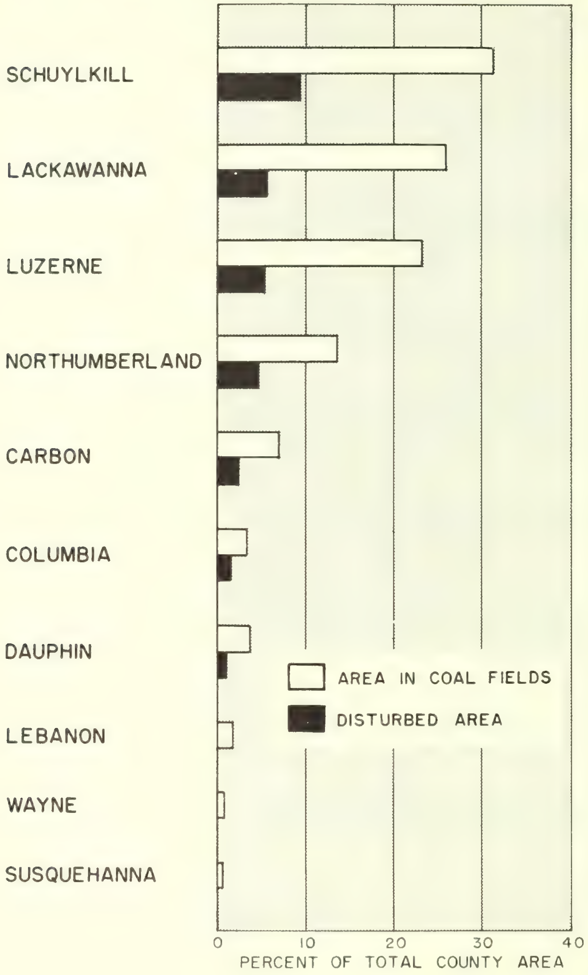


Figure 12.—The portions of the anthracite counties that lie within coal fields, and in the portions disturbed by mining—1962. In Lebanon, Wayne, and Susquehanna Counties only 0.10 percent or less of the total county area has been disturbed.



Of the 10 counties in which coal has been mined, Schuylkill, Luzerne, Lackawanna, and Northumberland Counties have always produced the greatest tonnages; they have produced 92 percent of the anthracite mined since World War II. As might be expected, these four counties now have the highest proportions of disturbed land: in rounded figures, 9 percent in Schuylkill, 5 percent in Luzerne and Lackawanna, and 4 percent in Northumberland (fig. 12). These figures, being based on total county area, are not in themselves very impressive. But they represent from 20 to 32 percent of the sections of those counties that lie within the Anthracite Region. And, in terms of people and the amenities of their surroundings, those percentages are important, for three-fourths of the people in the four counties live in the anthracite sections.

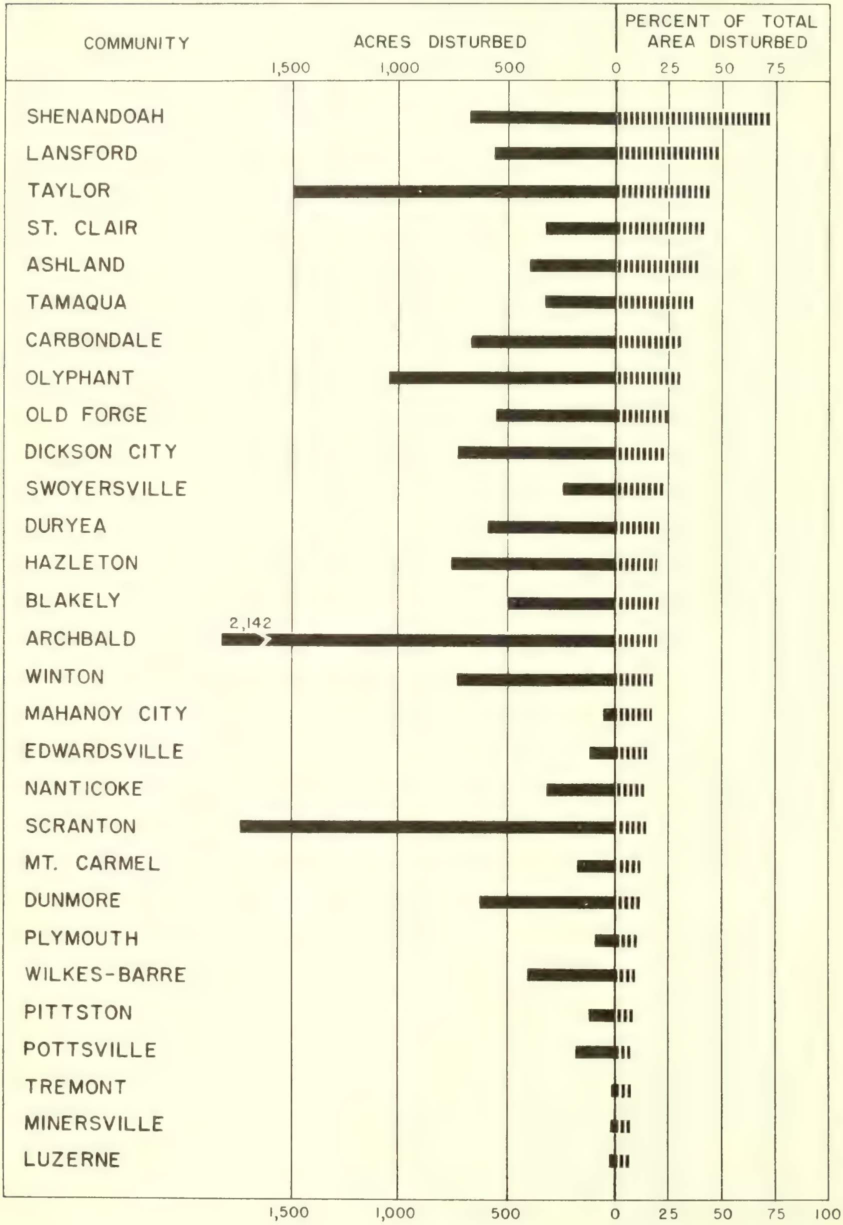
Indicative of the ubiquity of mining disturbances and their impact on the amenities of life in the Region are the figures on disturbances within municipal boundaries. One-third of the communities in the Region have 500 or more acres of strippings or deep-mine waste within their boundaries. Some 60 percent of the communities have had at least 10 percent of their surface area altered by mining, and 20 percent of them have had 30 to 70 percent of their surface area so altered. Some of these data are shown graphically in figure 13.

Table 6 (appendix II) gives a breakdown of all land area in the Region, by unit areas and counties, according to whether visible or not, disturbed or not, and if disturbed, kind of disturbance, and density of present tree cover. Since some unit areas include segments of two counties, and the table is set up on a county basis, some unit areas appear in two county listings. Hence there are 52 unit-area listings for the 41 unit areas that were recognized and mapped.

From the regional totals (table 6), several broad relationships that characterize surface conditions in the Anthracite Region may be pointed out:

1. One acre in 4 has been disturbed in some way by coal-mining activities.
2. Of the disturbed area, 1 acre in 4 is covered by deep-mine waste, and 3 acres are in strippings.
3. Of the disturbed area, 1 acre in 5 has adequate tree cover (51 to 100 percent), and 4 acres have inadequate cover.
4. Of the disturbed area, considerably less than half is visible from roads and hub communities; the ratio of visible to non-visible area is about 3 to 4.

Figure 13. — Disturbed land area within major communities. A few communities — Forty-Fort, Frackville, Lykens, McAdoo, and Tower City — have no disturbed area. Shamokin, West Hazleton, West Pittston, Kingston, and Freeland have less than 5 percent of their area disturbed.



Highway and Community Frontage Classification

That part of the landscape that abuts upon and is visible from highways and communities obviously exerts much more influence than more remote areas upon people's visual impressions of the Anthracite Region and upon their attitudes toward it as a place in which to live, work, and play. Therefore these highway and community frontage areas were classified separately.

Some 1,570 miles of frontage were classified. About 1,500 miles of this was along highways; it called for cruising about 750 miles of road and inspecting the land on both sides from the varying angles of view seen by traveling the roads in both directions. The remaining 70 miles of frontage were along segments of community boundaries that did not coincide with an important road.

Thirty percent of the total frontage — nearly 500 miles — showed mining disturbances of some sort. By counties, this varied from 14 percent in Dauphin and Lebanon Counties to 37 percent in Columbia County. Although the proportions of stripped land and deep-mine waste varied widely among counties, for the Region as a whole the two kinds of spoil accounted for equal proportions of the inadequately vegetated disturbed frontage, or 12 percent each of the total frontage (fig. 15). Inadequately vegetated deep-mine waste ranks higher in terms of frontage than in terms of visible area; it makes up only 40 percent of all inadequately vegetated, disturbed visible area in the Region. This difference occurs because much of the deep-mine waste is in huge conspicuous piles and near centers of population, so that it falls into the frontage category.

Disturbed areas on which enough trees have come in (51 to 100 percent cover) to be considered adequate revegetation made up a substantial part of the total disturbed frontage, and are a significant factor in visual impressions of it. For the Region as a whole, 6 percent of the total frontage, or 20 percent of the disturbed frontage, supports adequate tree cover (fig. 15).

Table 7 (appendix II) presents a more detailed breakdown of the data summarized in figure 15; the table gives figures for

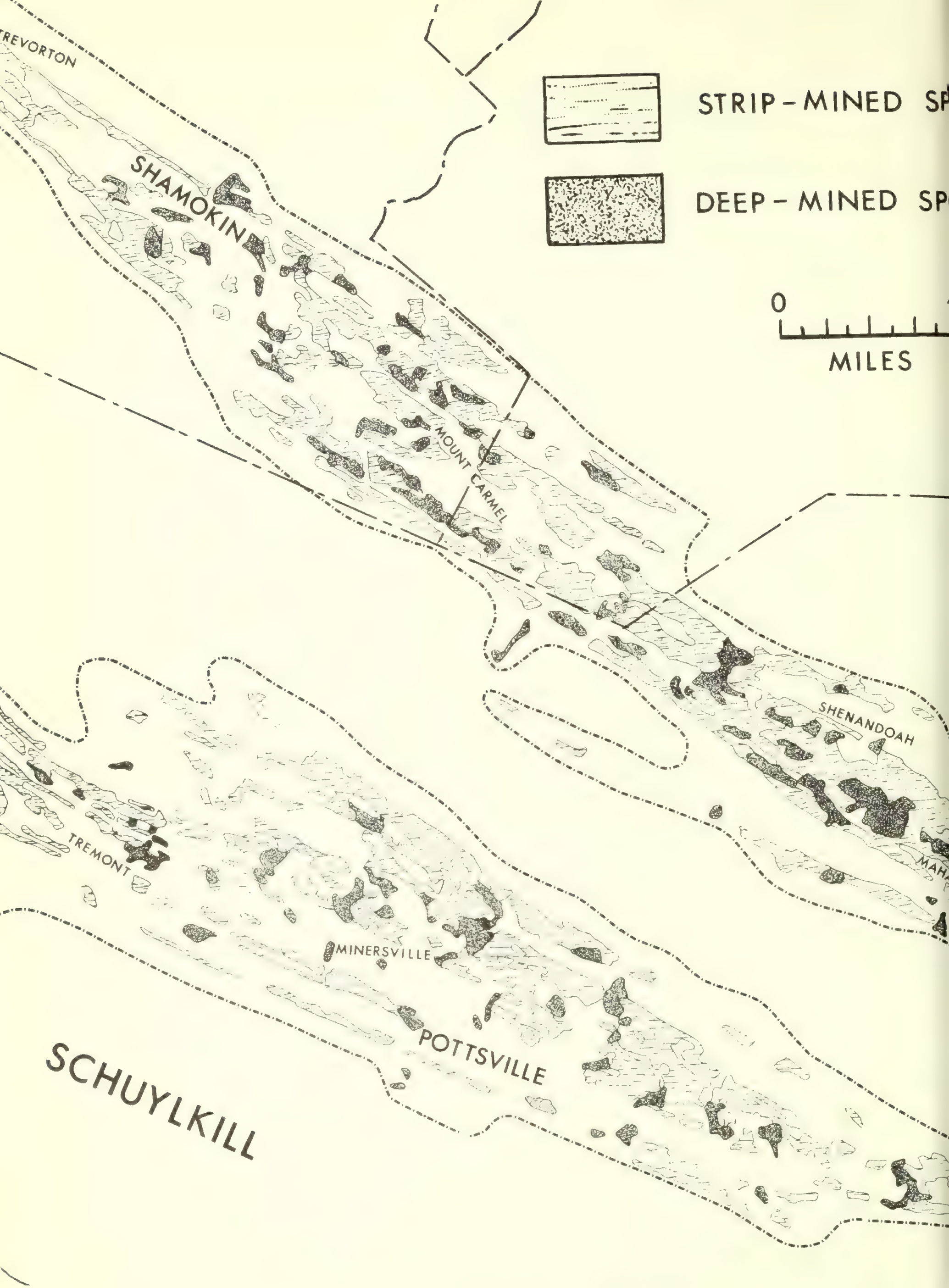
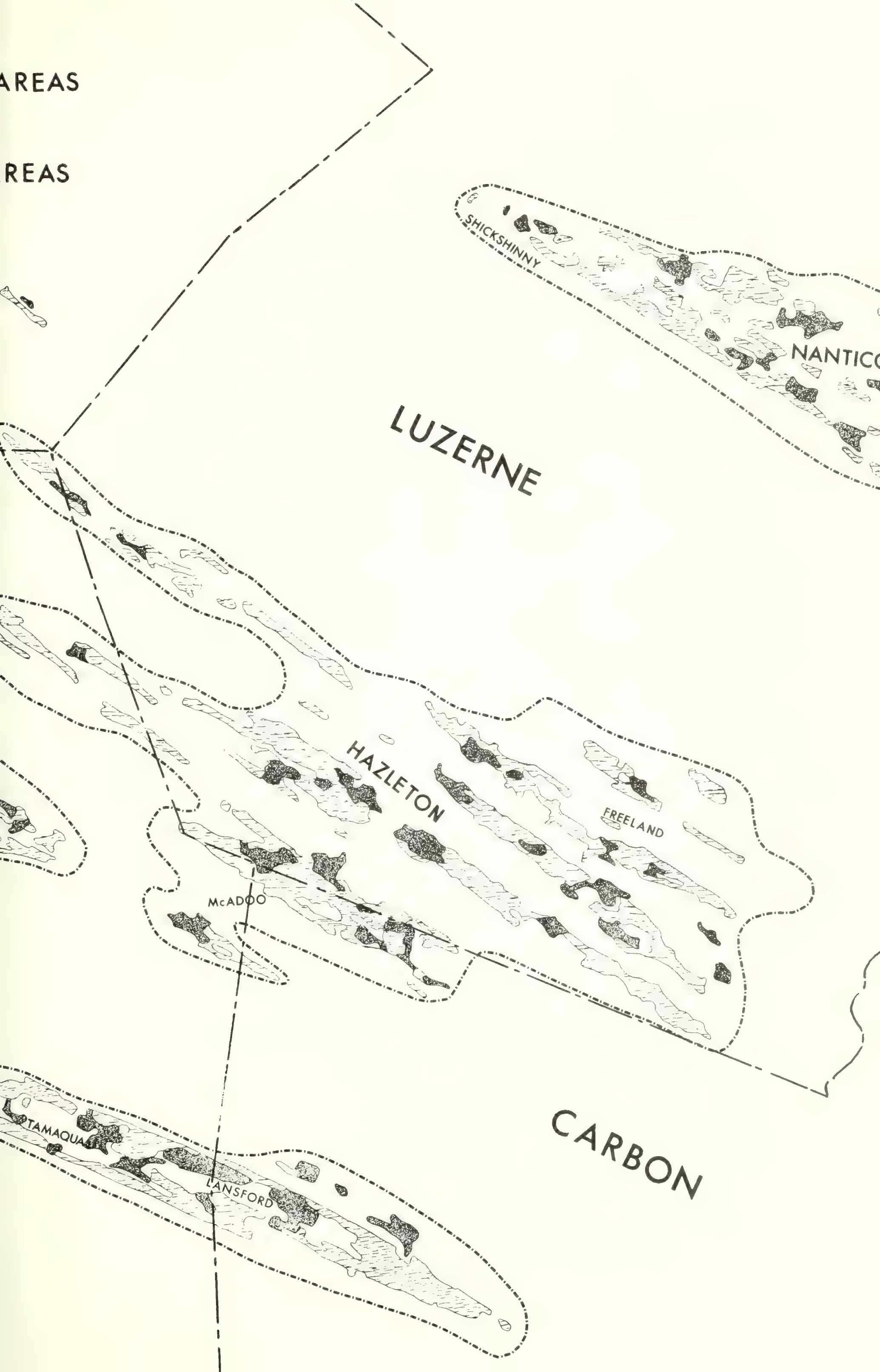


Figure 14. — A section from the regional map prepared to show the areas disturbed by coal mining in the Anthracite Region of Pennsylvania.


AREAS
REAS
SHICKSHINNY
NANTICO
LUZERNE
HAZLETON
FREELAND
McADOO
TAMAQUA
LANSFORD
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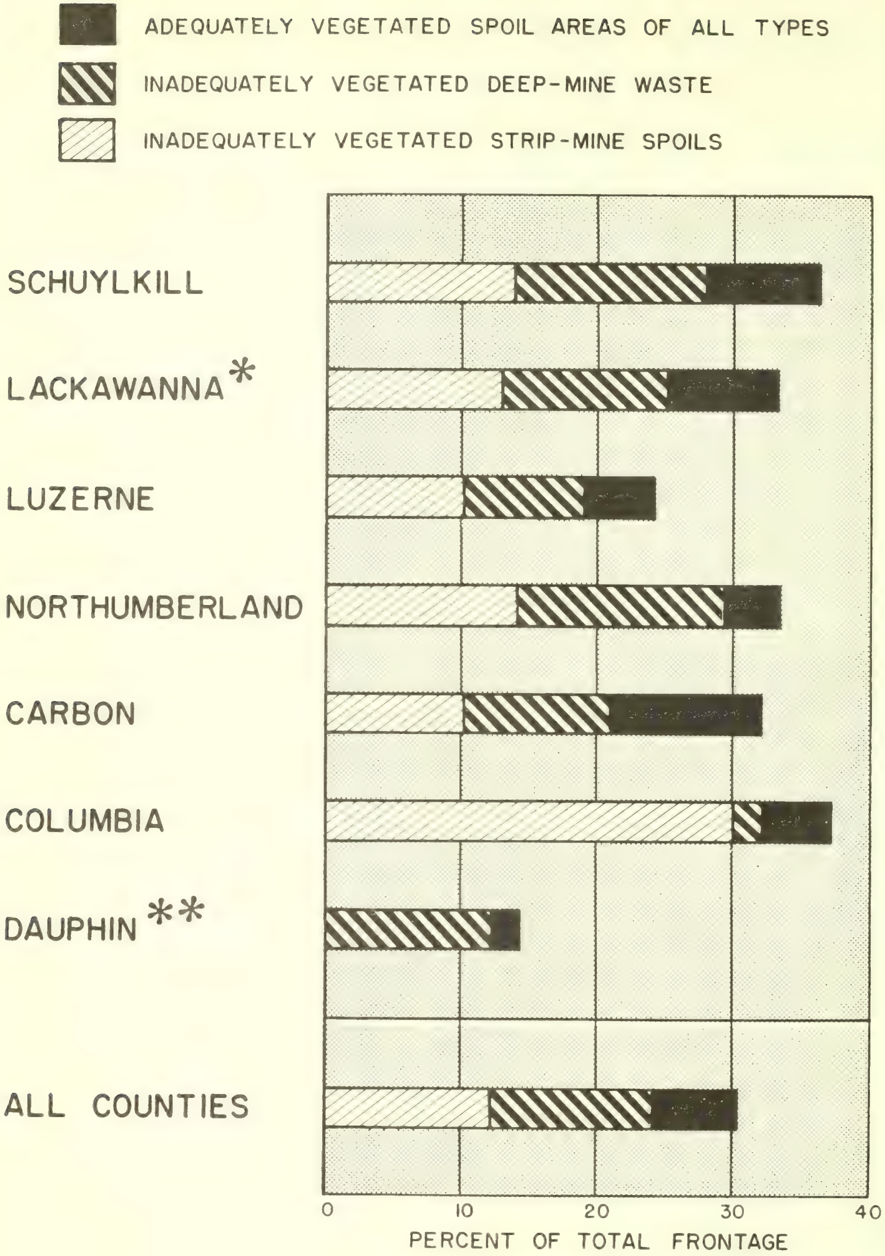

Figure 15. — Amount of highway frontage disturbed, and proportions of disturbed frontage adequately and inadequately vegetated, by counties — 1962. *Includes Susquehanna and Wayne Counties. **Includes Lebanon County.

unit areas as well as counties, and in miles of frontage as well as percentages.

MAPS

As noted under *Methods,* three series of maps were prepared: unit-area maps, county maps, and a regional map. This regional map appears in this report as figure 14, and a sample unit-area map appears as figure 5.

The 41 unit-area maps are the basic reference for the screen and cover plantings recommended in this report. Besides such conventional features as major roads and municipal boundaries, these maps show the disturbed areas by kind of disturbance (strip-mined or deep-mine waste), and density class of the tree cover (0-10, 11-50, or 51-100 percent) on the disturbed land. Thus they picture much of the information that is tabulated in tables 6 and 7 (appendix II). In fact, the areas and distances in those tables were scaled from the unit-area maps.

The unit-area maps also show the limits of visibility from highways and communities. And, most important for planning community action programs, they show the locations where trees could eventually shield or obscure the more conspicuous spoils — that is, potential forest screen and forest cover planting sites. Also marked are the locations of potential water-recreation sites.

The 10 county maps, which are composites of the unit-area maps at a reduced scale, show the relationships of all the unit-areas in a county to each other with respect to location, boundaries, and comparative size. And they picture on one map the areas to which the county data (appendix II) apply. No sample of a county map is included in this report.

PLANTING-STOCK REQUIREMENTS

Once a community program has been adopted and planting sites have been selected, careful planning is required to assure that the requisite quantities and species of planting stock may be on hand at the proper time. Orders for stock should be placed with the state nurseries several months before the planting season. Delay may mean that the desired seedlings are no longer available. In the event of a really large-scale program, requiring hundreds of thousands of trees, it might be necessary to make arrangements with the nurseries at least 2 years in advance.

Requirements for Screen and Cover Sites

The initial planting effort should be concentrated on hiding or obscuring the most conspicuous and most unsightly areas. The potential planting sites indicated on the unit-area maps were selected for this purpose. Planting-stock requirements for these recommended screen and cover plantings are given in tables 8 and 9, respectively, by unit areas and by counties. Totals for counties also are shown, together with the requirements for other site categories, in figure 16. All estimates of planting-stock requirements are based on 6- by 6-foot spacing of the trees.

Planting-stock requirements are given for two optional screen widths — recommended and minimum (table 8). The latter is included because, in some instances, limited financial means or present use of a site may preclude planting more than the 25-foot minimum width. Although greater widths, up to as much as 100 feet, usually would be preferable, 25-foot screens nevertheless will be fairly effective in most places.

Less than a million trees (856,000) would be required to plant screens of the recommended widths on all the areas designated for forest screening. At the minimum width of 25 feet, only about 285,000 trees would be required. Considering the aesthetic benefits to be derived from the successful establishment of these screens, even the larger number of seedlings is not overwhelming or impractical.

Considerably larger quantities of stock — 19 million — would be needed for the recommended cover plantings. However, if the entire recommended areas could not be planted, substantial benefits could be achieved in many places with fewer trees by establishing screens on or near the disturbed areas.

Requirements for Other Visible Areas

After the most critical areas have been treated, the next step would be to plant the remaining visible disturbed areas. Included in this category are the areas behind screen plantings (which will be visible until the screens are well developed), and areas that for one reason or another are not so offensive as those designated for attention in the initial effort. Chiefly, these are areas between the 2,000-foot limit of frontage areas and the 1-mile visibility limit. A program to plant these other visible areas would require about 25 million additional trees. These requirements, by counties, are shown in figure 16.

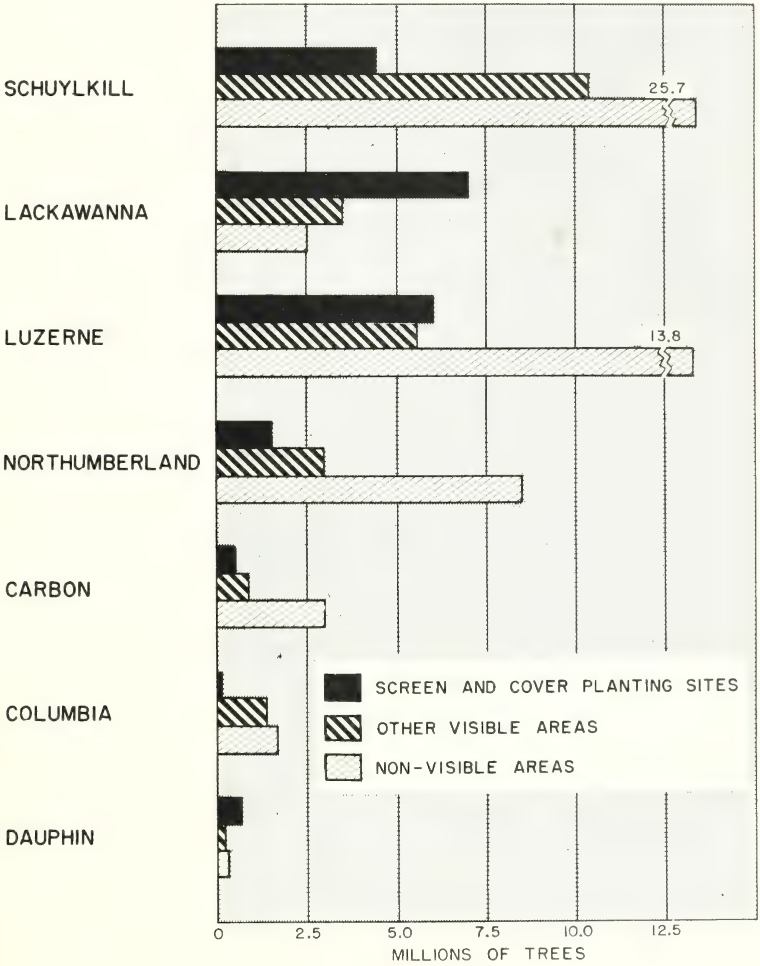

Figure 16. — Trees required to plant disturbed areas having less than 50 percent tree cover in 1962, by counties. Requirements for Lebanon, Wayne, and Susquehanna Counties are 200,000 trees each, or less.

Non-Visible Areas

The extensive areas of disturbance that cannot be seen from highways and centers of human activity do not materially detract from the natural beauty of the coal-mining sections. However, many of these areas — strip-mined lands in particular — are subject to erosion and contribute to stream pollution and siltation. Hence they must be considered in any plan for a complete reforestation program in the Anthracite Region. To plant these areas would require about 55 million trees. These requirements, too, are shown by counties in figure 16.

SPECIES RECOMMENDATIONS

The proper choice of species, and their positions in a roadside screen, are important for rapid initial effects and for long-time shielding. Slow-growing evergreens like the spruces, which hold their branches for many years, should be planted in the front portion of a screen. The central portion should consist of faster growing evergreens, such as pines. The portion farthest from the road should be planted to still faster growing species, which can be deciduous. Black locust and Japanese and European larches are suitable for this position. Hybrid poplars and some of the European species of alder also have promise as fast-growing trees, but have not been sufficiently tested on anthracite spoils to justify recommending them. The composition of a screen 50 feet in width might be, for example: 3 rows of spruce in front, 3 rows of pine in the middle, and 3 rows of black locust in the rear.

Although species selection is of less importance in cover plantings, coniferous species that retain their foliage throughout the year generally are preferable. However, deciduous trees are fairly effective when well established, and the commonly planted ones — black locust and the larches — possess the added virtue of growing faster than the evergreens. If some of the hybrid poplars and alders prove to be well adapted to anthracite spoils, they could also be listed among the fast-growing deciduous species for cover planting.

SUMMARY

A survey of the Anthracite Region of Pennsylvania was made in 1962 to locate and map potential planting sites where trees could be used most effectively to screen from view or to cover unsightly mine-spoil areas. The report and its supplements are intended to serve as a guide for planning community tree-planting programs for aesthetic improvement of the Anthracite Region.

Total area covered by the survey was 706 square miles. This included essentially all lands disturbed by coal mining, plus the surrounding terrain to effective visibility barriers such as ridge tops or forest. Total area classified as disturbed by mining activities was 112,000 acres.

The major emphasis in visibility classification was on highway frontage — the land within 2,000 feet on either side of a road — plus some frontage abutting on community borders. Some 1,570 miles of frontage were inspected, of which 30 percent, or almost 500 miles, exhibited some sort of mining disturbance.

The mapping was done by unit areas, which varied in size from 1,400 to 27,000 acres. Forty-one such unit areas were recognized and mapped. Each includes a city, borough, or other population center, which is designated as its hub, and is expected to provide leadership in community planting programs.

Shown on the unit-area maps are major highways, political boundaries, visibility limits, and the land-classification categories pertaining to disturbance, kind of spoil, and density of present tree cover. Superimposed on these features are recommended locations for forest screen plantings, forest cover plantings, and potential water-recreation areas.

County maps were prepared by combining unit-area maps and reducing the scale. A generalized regional map also was prepared.

Three categories of disturbed land were recognized with respect to priority for planting: (1) the most conspicuous, most unsightly, visible areas; (2) other, less critical, visible areas; and (3) non-visible areas.

In the first category, which comprises the sites designated on the unit-area maps for planting, 481 sites are recommended for screen plantings and 358 for cover plantings. To plant all these sites to recommended standards would require about 20 million trees. Of these, some 19 million trees would go into the cover plantings, whereas less than a million trees would be needed for the screen plantings.

A complete reforestation program for all three categories would require 100 million seedlings.

The unit-area maps (except one sample), the county maps, and a mass of related tabular data are not included in this report. This material is available in limited quantities from the Pennsylvania Power and Light Company and the Northeastern Forest Experiment Station.

■

APPENDIX

I

DATA FOR PITTSTON UNIT AREA

Table 1. — Land area classification

PITTSTON UNIT AREA

Classification	Unit area		Visible area		City	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
Total	9,873	100	4,473	100	1,184	100
Not disturbed	7,510	76	3,467	78	1,082	91
Disturbed:	2,363	24	1,006	22	102	9
Strip-mined:	1,793	18	558	12	23	2
0-10% tree cover	862	9	308	7	20	2
11-50% tree cover	217	2	77	1	3	(1)
51-100% tree cover	714	7	173	4	0	0
Deep-mine waste:	570	6	448	10	79	7
0-10% tree cover	520	5	423	9	79	7
11-50% tree cover	25	(1)	15	(1)	0	0
51-100% tree cover	25	(1)	10	(1)	0	0

[1] Less than 1 percent.

Table 2. — Highway visibility classification

PITTSTON UNIT AREA

Classification	Miles	Percent
Total frontage[1]	54.8	100
Not disturbed	38.9	71
Disturbed:	15.9	29
Strip-mined	6.3	11
Deep-mine waste	5.9	11
Revegetated spoils[2]	3.7	7

[1] Frontage, measured in miles, is a strip of land 2,000 feet wide, parallel to and on both sides of highways and near developed areas of unit-area communities.

[2] Disturbed areas supporting more than 50 percent tree cover.

Table 3. — Potential water-recreation sites

PITTSTON UNIT AREA

Site No.	Size class, in acres	Site condition	General location
1	1-5	Channel	Gardner Creek bridge in Laflin.

Table 4. — Potential forest screen planting sites
PITTSTON UNIT AREA

Site No.	Width and Length	Size	Existing tree cover	Trees required	Spoil type[1]	Site preparation required[2]	Location
	Feet	*Acres*	*Percent*	*No.*			
1	100 x 500	1.15	0-10	1,380	ND	Minor	Highway overpass N on E side of River Street.
2	100 x 1300	2.98	0-10	3,576	ND	None to minor	Highway overpass S on E side of River Street.
3	100 x 700	1.61	0-10	1,932	P&ND	None	Yatesville Road S on E side of Pittston bypass.
4	100 x 1300	2.98	0-10	3,576	P&ND	None to minor	Pole A 234 N on W side of Main Street.
5	100 x 900	2.07	0-10	2,484	ND	None	Pole A 228 N on E side of Main Street.
6	100 x 800	1.84	11-50	1,656	ND	None	Pole 299 N on W side of Main Street.
7	100 x 500	1.15	0-10	1,380	S	None	Pole X 94 E of S side of Yatesville Road.
8	75 x 300	.52	0-10	624	ND	None	Transco R/W E & W on N side of Main Street.
9	100 x 400	.92	0-10	1,104	ND	None	Pole LAF 9/X11 W on N side of Main Street.
10	25 x 400	.23	11-50	207	S	None	Pole LAF 9/X11 W on S side of Main Street.
11	100 x 400	.92	0-10	1,104	ND	None	18 Main Street S.
12	100 x 200	.46	11-50	414	ND	None	27 Main Street S.
13	100 x 900	2.07	0-10	2,484	P&ND	None	Pa. Turnpike overpass N on W side of Pa. 315.
14	100 x 200	.46	0-10	552	P	None	Pole 1010 W on S side of Westminster-Bear Creek Road.
Total	—	19.36	—	22,473	—	—	—

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[1] S = strip-mined. P = deep-mine waste. ND = not disturbed.

[2] Minor = grading recommended. Major = grading and backfilling recommended.

Table 5. — Potential forest cover planting sites
PITTSTON UNIT AREA

Spoil type[1]	Existing tree cover	Approx. area	Trees required	General location
	Percent	*Acres*	*No.*	
P	0-10	41	49,200	In Port Griffith.
S&P	0-10	74	88,800	W of Main Street in Upper Pittston.
P	0-10	18	21,600	E of Main Street in Upper Pittston.
P	0-10	31	37,200	NW section of Hughestown.
P	0-10	49	56,400	N-central section of Hughestown.
	11-50			
S	0-10	51	58,200	In Browntown and NW section of Yatesville.
	11-50			
S	0-10	18	21,600	In S-central section of Yatesville.
S&P	0-10	153	172,800	On both sides of U.S. 11 in and S of Hughestown.
	11-50			
S	0-10	13	15,600	Near Old Boston on E side of Pa. Turnpike.
S	0-10	82	98,400	At Wyoming Valley Interchange of Pa. Turnpike.
S	0-10	23	27,600	E of Pa. 315 near Dupont line.
S	11-50	8	7,200	E of Pa. 315 along Dupont line.
Total	—	561	654,600	—

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[1] S = strip-mined. P = deep-mine waste.

APPENDIX

II

UNIT AREA AND COUNTY DATA

Table 6. — Land area classification: total area and visible area in different tree-cover density classes, by disturbance categories, counties, and unit-areas
(In acres)

Unit area	Strip-mined land, percent tree cover			Deep-mine waste, percent tree cover			Not disturbed	Total
	0-10	11-50	51-100	0-10	11-50	51-100		
CARBON COUNTY								
Freeland:								
Total area[1]	0	0	25	0	0	0	298	323
Visible area	0	0	0	0	0	0	0	0
Hazleton:								
Total area	806	252	637	409	39	15	3,364	5,522
Visible area	284	79	150	107	3	0	992	1,615
Lansford:								
Total area	969	755	906	547	230	281	8,387	12,075
Visible area	41	148	280	427	200	209	4,325	5,630
County total:								
Total area	1,775	1,007	1,568	956	269	296	12,049	17,920
Visible area	325	227	430	534	203	209	5,317	7,245
COLUMBIA COUNTY								
Ashland:								
Total area	1,625	427	348	611	0	20	6,252	9,283
Visible area	667	244	205	399	0	8	1,712	3,235
West Hazleton:								
Total area	15	0	41	0	0	0	306	362
Visible area	0	0	0	0	0	0	0	0
Scotch Valley:[2]								
Total area	38	71	0	20	0	0	0	129
Visible area	0	0	0	0	0	0	0	0

County total:								
Total area	1,678	498	389	631	0	20	6,558	9,774
Visible area	667	244	205	399	0	8	1,712	3,235
DAUPHIN COUNTY								
Lykens:								
Total area	242	59	102	380	293	61	10,278	11,415
Visible area	0	0	0	380	293	61	5,949	6,683
Rush Township:								
Total area	0	0	31	0	0	0	377	408
Visible area	0	0	0	0	0	0	28	28
County total:								
Total area	242	59	133	380	293	61	10,655	11,823
Visible area	0	0	0	380	293	61	5,977	6,711
LACKAWANNA COUNTY								
Archbald:								
Total area	766	891	707	296	43	54	10,020	12,777
Visible area	628	669	635	296	43	54	8,129	10,454
Blakely:								
Total area	240	82	38	87	31	23	2,054	2,555
Visible area	240	82	38	87	31	23	1,998	2,499
Carbondale:								
Total area	1,688	390	810	449	64	33	10,245	13,679
Visible area	731	84	394	360	54	33	4,026	5,682
Dickson City:								
Total area	378	59	112	173	20	0	2,559	3,301
Visible area	378	59	112	173	20	0	2,363	3,105
Dunmore:								
Total area	89	51	217	385	109	33	6,832	7,716
Visible area	33	20	166	352	89	33	5,266	5,959
Old Forge:								
Total area	329	43	102	173	66	43	2,844	3,600
Visible area	329	43	102	173	66	43	2,546	3,302

CONTINUED

Table 6. — Continued

Unit area	Strip-mined land, percent tree cover			Deep-mine waste, percent tree cover			Not disturbed	Total
	0-10	11-50	51-100	0-10	11-50	51-100		
LACKAWANNA COUNTY, continued								
Olyphant:								
Total area	598	99	291	296	38	74	3,948	5,344
Visible area	522	76	212	245	15	74	2,563	3,707
Scranton:								
Total area	376	499	521	676	160	28	15,145	17,405
Visible area	373	466	411	653	140	28	12,867	14,938
Taylor:								
Total area	603	123	354	381	23	74	2,459	4,017
Visible area	603	123	354	381	23	74	2,339	3,897
Winton:								
Total area	245	166	181	148	0	0	4,079	4,819
Visible area	230	161	171	148	0	0	2,709	3,419
County total:								
Total area	5,312	2,403	3,333	3,064	554	362	60,185	75,213
Visible area	4,067	1,783	2,595	2,868	481	362	44,806	56,962
LEBANON COUNTY								
Rush Township:								
Total area	146	31	44	0	0	0	3,722	3,943
Visible area	3	0	13	0	0	0	102	118
County total:								
Total area	146	31	44	0	0	0	3,722	3,943
Visible area	3	0	13	0	0	0	102	118

Duryea:							
Total area	198	36	135	497	21	8	5,249	6,144
Visible area	183	28	125	477	13	0	3,063	3,889
Edwardsville:								
Total area	255	8	109	117	26	20	2,455	2,990
Visible area	23	0	15	107	18	0	952	1,115
Forty-Fort:								
Total area	0	0	0	26	0	0	1,870	1,896
Visible area	0	0	0	0	0	0	1,490	1,490
Freeland:								
Total area	2,173	621	1,435	985	73	16	17,395	22,698
Visible area	418	67	110	132	13	0	2,163	2,903
Hazleton:								
Total area	1,503	566	1,144	1,565	29	0	12,141	16,948
Visible area	881	276	228	985	13	0	6,645	9,028
Kingston:								
Total area	0	0	0	0	0	33	1,407	1,440
Visible area	0	0	0	0	0	33	1,407	1,440
Luzerne:								
Total area	0	28	18	30	0	8	1,299	1,383
Visible area	0	5	10	30	0	8	735	788
McAdoo:								
Total area	1,074	11	166	245	0	0	4,209	5,705
Visible area	13	8	18	59	0	0	199	297
Nanticoke:								
Total area	2,058	598	1,025	1,364	78	206	16,140	21,469
Visible area	755	139	382	796	61	80	6,963	9,176
Pittston:								
Total area	862	217	714	520	25	25	7,510	9,873
Visible area	308	77	173	423	15	10	3,467	4,473
Plymouth:								
Total area	559	79	181	291	61	13	4,638	5,822
Visible area	332	69	79	217	51	8	3,574	4,330

CONTINUED

Table 6. — Continued

Unit area	Strip-mined land, percent tree cover			Deep-mine waste, percent tree cover			Not disturbed	Total
	0-10	11-50	51-100	0-10	11-50	51-100		
LUZERNE COUNTY, continued								
Swoyersville:								
Total area	156	296	69	148	0	0	2,803	3,472
Visible area	69	61	5	130	0	0	1,359	1,624
West Hazleton:								
Total area	549	260	508	99	15	0	8,263	9,693
Visible area	33	5	87	64	15	0	1,635	1,839
West Pittston:								
Total area	28	23	8	154	92	44	2,902	3,251
Visible area	23	0	0	77	54	18	1,859	2,031
Wilkes-Barre:								
Total area	1,859	1,167	459	697	46	25	15,260	19,513
Visible area	1,423	736	118	507	46	0	9,165	11,995
County total:								
Total area	11,274	3,910	5,971	6,738	466	398	103,541	132,298
Visible area	4,461	1,471	1,350	4,004	299	157	44,676	56,418
NORTHUMBERLAND COUNTY								
Mount Carmel:								
Total area	2,244	1,655	788	1,589	46	0	8,757	15,079
Visible area	605	395	119	648	13	0	2,165	3,945
Shamokin:								
Total area	2,118	562	350	1,157	29	63	12,059	16,338
Visible area	270	206	52	727	23	23	3,858	5,159
Trevorton:								
Total area	1,458	253	138	287	0	6	6,537	8,679
Visible area	620	138	40	287	0	6	2,967	4,058

County total:								
Total area	5,820	2,470	1,276	3,033	75	69	27,353	40,096
Visible area	1,495	739	211	1,662	36	29	8,990	13,162
SCHUYLKILL COUNTY								
Ashland:								
Total area	1,486	285	334	399	34	4	3,493	6,035
Visible area	493	210	242	301	34	4	1,955	3,239
Frackville:								
Total area	686	74	459	653	10	28	7,363	9,273
Visible area	515	8	252	597	10	28	2,513	3,923
Mahanoy City:								
Total area	2,025	301	778	715	8	54	6,549	10,430
Visible area	941	61	398	233	8	36	2,166	3,843
McAdoo:								
Total area	1,194	248	482	354	38	18	8,546	10,880
Visible area	92	8	46	94	0	18	2,337	2,595
Minersville:								
Total area	3,322	1,550	1,472	1,362	120	46	19,496	27,368
Visible area	1,215	315	178	570	25	0	3,354	5,657
Mount Carmel:								
Total area	54	26	0	5	0	5	666	756
Visible area	0	0	0	5	0	5	332	342
Pottsville:								
Total area	447	424	1,193	738	55	23	10,001	12,881
Visible area	126	57	332	336	55	0	5,934	6,840
St. Clair:								
Total area	2,779	912	912	570	48	0	9,873	15,094
Visible area	725	134	131	292	37	0	1,849	3,168
Shenandoah:								
Total area	1,875	584	758	1,196	31	31	3,865	8,340
Visible area	923	270	324	563	0	0	1,283	3,363
Tamaqua:								
Total area	2,447	501	1,291	1,089	143	213	8,029	13,713
Visible area	1,088	257	626	743	143	171	2,981	6,009

CONTINUED

Table 6. — Continued

Unit area	Strip-mined land, percent tree cover			Deep-mine waste, percent tree cover			Not disturbed	Total
	0-10	11-50	51-100	0-10	11-50	51-100		
SCHUYLKILL COUNTY, continued								
Tower City:								
Total area	1,530	334	722	597	20	10	17,186	20,399
Visible area	372	38	140	355	20	10	6,671	7,606
Tremont:								
Total area	2,117	961	292	746	29	17	16,022	20,184
Visible area	189	54	28	166	0	17	3,345	3,799
West Hazleton:								
Total area	166	31	43	31	0	0	622	893
Visible area	0	0	0	0	0	0	0	0
County total:								
Total area	20,128	6,231	8,736	8,455	536	449	111,711	156,246
Visible area	6,679	1,412	2,697	4,255	332	289	34,720	50,384
SUSQUEHANNA COUNTY								
Carbondale:								
Total area	79	28	36	31	10	10	1,656	1,850
Visible area	79	28	36	31	10	10	1,500	1,694
County total:								
Total area	79	28	36	31	10	10	1,656	1,850
Visible area	79	28	36	31	10	10	1,500	1,694
WAYNE COUNTY								
Carbondale:								
Total area	39	0	28	43	36	23	2,306	2,475
Visible area	31	0	28	43	36	23	900	1,061

Total area	39	0	28	43	36	23	2,306	2,475
Visible area	31	0	28	43	36	23	900	1,061
Total, region								
Total area[1]	46,493	16,637	21,514	23,331	2,239	1,688	339,736	451,638
Visible area	17,807	5,904	7,565	14,176	1,690	1,148	148,700	196,990

[1] Includes visible-area figures.

[2] A small mining section not included as part of a unit area nor contiguous to a major coal field but classified as part of the Eastern-Middle Field.

Table 7. — Frontage classification according to amount and kind of disturbance and amount of disturbed frontage revegetated

Unit area[1]	Disturbed, inadequately vegetated (0-50 percent)				Disturbed, adequately vegetated (51-100 percent)		Not disturbed		Total	
	Strip-mined land		Deep-mine waste							
	Miles	%	*Miles*	%	*Miles*	%	*Miles*	%	*Miles*	%
CARBON COUNTY										
Hazleton	5.1	27	3.0	16	1.4	7	9.4	50	18.9	100
Lansford	1.5	3	4.7	10	5.8	12	36.5	75	48.5	100
Total	6.6	10	7.7	11	7.2	11	45.9	68	67.4	100
COLUMBIA COUNTY										
Ashland	6.6	30	0.6	2	1.1	5	14.0	63	22.3	100
Total	6.6	30	0.6	2	1.1	5	14.0	63	22.3	100
DAUPHIN COUNTY[2]										
Lykens	0.0	0	5.3	13	0.3	1	33.3	86	38.9	100
Rush Township	.0	0	.0	0	.5	9	4.8	91	5.3	100
Total	0.0	0	5.3	12	0.8	2	38.1	86	44.2	100
LACKAWANNA COUNTY[3]										
Archbald	9.1	20	4.0	9	5.6	12	26.5	59	45.2	100
Blakely	2.0	11	1.9	10	.7	4	14.0	75	18.6	100
Carbondale	10.4	17	6.9	11	6.0	10	37.3	62	60.6	100
Dickson City	2.6	18	2.5	18	.8	6	8.2	58	14.1	100
Dunmore	.8	3	6.1	19	.9	3	24.0	75	31.8	100
Old Forge	.9	5	3.2	19	1.9	11	11.1	65	17.1	100

Scranton	8.5	8	11.9	12	4.7	4	78.4	76	103.5	100
Taylor	7.6	31	3.7	15	3.6	15	9.6	39	24.5	100
Winton	1.4	11	.8	7	.4	3	9.5	79	12.1	100
Total	44.4	13	42.1	12	25.9	8	227.4	67	339.8	100
LUZERNE COUNTY										
Duryea	1.9	6	5.0	15	2.4	7	24.1	72	33.4	100
Edwardsville	.9	10	1.0	11	.4	4	7.1	75	9.4	100
Forty-Fort	.0	0	.0	0	.0	0	11.0	100	11.0	100
Freeland	4.1	14	.6	2	2.5	8	23.0	76	30.2	100
Hazleton	7.7	11	7.2	10	3.6	5	52.6	74	71.1	100
Kingston	.0	0	.0	0	.0	0	9.3	100	9.3	100
Luzerne	.3	2	.2	2	.4	3	11.2	93	12.1	100
McAdoo	1.0	13	.5	6	.5	6	5.7	75	7.7	100
Nanticoke	5.5	8	10.3	16	6.1	9	44.2	67	66.1	100
Pittston	6.3	11	5.9	11	3.7	7	38.9	71	54.8	100
Plymouth	4.0	13	3.1	11	1.5	5	21.4	71	30.0	100
Swoyersville	1.3	11	1.7	14	.2	1	9.0	74	12.2	100
West Hazleton	1.1	3	1.5	5	2.5	8	27.6	84	32.7	100
West Pittston	.2	1	2.1	9	.8	4	18.6	86	21.7	100
Wilkes-Barre	17.4	16	8.7	8	1.9	2	80.7	74	108.7	100
Total	51.7	10	47.8	9	26.5	5	384.4	76	510.4	100
NORTHUMBERLAND COUNTY										
Mount Carmel	10.0	18	6.5	12	2.5	5	35.1	65	54.1	100
Shamokin	4.0	10	7.4	19	1.1	3	26.7	68	39.2	100
Trevorton	2.2	10	3.5	15	1.0	4	16.4	71	23.1	100
Total	16.2	14	17.4	15	4.6	4	78.2	67	116.4	100
SCHUYLKILL COUNTY										
Ashland	2.5	10	7.6	31	0.4	2	14.2	57	24.7	100
Frackville	5.2	19	5.5	20	.7	2	16.1	59	27.5	100
Mahanoy City	8.9	20	5.3	12	5.1	12	25.0	56	44.3	100

CONTINUED

Table 7. — Continued

Unit area[1]	Disturbed, inadequately vegetated (0-50 percent)				Disturbed, adequately vegetated (51-100 percent)		Not disturbed		Total	
	Strip-mined land		Deep-mine waste							
	Miles	%	*Miles*	%	*Miles*	%	*Miles*	%	*Miles*	%
McAdoo	2.3	8	2.3	8	1.4	4	24.6	80	30.6	100
Minersville	16.2	25	11.7	19	4.8	8	30.6	48	63.3	100
Mount Carmel	.0	0	.5	6	.2	2	7.6	92	8.3	100
Pottsville	2.7	4	6.9	10	3.7	6	54.1	80	67.4	100
St. Clair	6.6	19	4.2	12	3.3	10	20.1	59	34.2	100
Shenandoah	8.4	22	5.1	14	4.8	13	18.8	51	37.1	100
Tamaqua	5.9	15	9.8	24	5.6	14	18.6	47	39.9	100
Tower City	3.0	8	3.9	10	2.2	6	29.7	76	38.8	100
Tremont	4.7	9	5.0	9	2.0	4	41.0	78	52.7	100
Total	66.4	14	67.8	14	34.2	8	300.4	64	468.8	100
Total, region	191.9	12	188.7	12	100.3	6	1,088.4	70	1,569.3	100

[1] Unit areas with no frontage in a designated county are not listed.
[2] Includes Lebanon County.
[3] Includes Susquehanna and Wayne Counties.

Table 8. — Planting-stock requirements for forest screen plantings at minimum and at recommended widths, by unit areas and counties

Unit area[1]	Sites	Length of screens	Trees required at —	
			Minimum width of 25 feet	Recommended width
	No.	*Feet*	*No.*	*No.*
CARBON COUNTY				
Hazleton	23	19,700	13,308	41,223
Lansford	8	7,800	4,920	12,963
Total	31	27,500	18,228	54,186
COLUMBIA COUNTY				
Ashland	13	18,900	10,914	35,127
Total	13	18,900	10,914	35,127
LACKAWANNA COUNTY				
Archbald	21	9,100	5,874	18,948
Blakely	2	1,600	852	2,001
Carbondale	12	11,300	7,524	28,056
Dickson City	2	1,000	684	2,136
Dunmore	3	600	306	1,134
Olyphant	3	600	339	960
Winton	3	800	489	957
Total	46	25,000	16,068	54,192
LUZERNE COUNTY				
Freeland	12	14,400	9,258	29,901
Hazleton	32	25,500	16,272	50,670
McAdoo	4	4,000	2,760	5,928
Nanticoke	9	8,700	5,718	17,028
Pittston	14	8,800	5,832	22,473
Swoyersville	3	1,600	1,104	4,416
West Hazleton	4	2,300	1,428	3,528
West Pittston	3	2,600	1,506	5,850
Wilkes-Barre	22	21,500	13,839	47,943
Total	103	89,400	57,717	187,737
NORTHUMBERLAND COUNTY				
Mount Carmel	37	28,100	17,871	54,615
Shamokin	16	16,000	10,137	26,805
Trevorton	3	12,800	8,820	18,192
Total	56	56,900	36,828	99,612

CONTINUED

Table 8. — Continued

Unit area[1]	Sites	Length of screens	Trees required at — Minimum width of 25 feet	Trees required at — Recommended width
	No.	*Feet*	*No.*	*No.*
		SCHUYLKILL COUNTY		
Ashland	9	10,000	6,303	25,245
Frackville	19	26,300	15,822	40,113
Mahanoy City	31	37,800	24,033	73,902
McAdoo	14	6,900	4,695	10,131
Minersville	46	36,400	23,736	78,456
Mount Carmel	2	1,000	522	774
Pottsville	16	12,400	8,430	25,230
St. Clair	16	15,400	9,039	26,829
Shenandoah	12	22,800	14,808	47,352
Tamaqua	25	27,000	17,916	49,989
Tower City	16	15,100	9,813	19,083
Tremont	20	12,500	7,950	23,268
Total	226	223,600	143,067	420,372
		SUSQUEHANNA COUNTY		
Carbondale	5	1,700	1,158	2,991
Total	5	1,700	1,158	2,991
		WAYNE COUNTY		
Carbondale	1	1,000	684	1,380
Total	1	1,000	684	1,380
Total, region	481	444,000	284,664	855,597

[1] Counties and unit areas with no screen plantings are not listed.

Table 9. — Planting-stock requirements for forest cover plantings, by unit-areas and counties

Unit area[1]	Sites	Area of sites	Trees required
	No.	*Acres*	*No.*
	CARBON COUNTY		
Hazleton	1	36	43,200
Lansford	7	446	448,800
Total	8	482	492,000
	COLUMBIA COUNTY		
West Hazleton	1	31	37,200
Total	1	31	37,200
	DAUPHIN COUNTY		
Lykens	5	552	567,300
Total	5	552	567,300
	LACKAWANNA COUNTY		
Archbald	13	410	414,300
Blakely	6	195	211,800
Carbondale	11	630	732,900
Dickson City	5	345	390,300
Dunmore	10	446	510,000
Old Forge	13	445	502,500
Olyphant	9	675	805,500
Scranton	34	1,618	1,762,800
Taylor	24	1,014	1,182,900
Winton	8	353	420,600
Total	133	6,131	6,933,600
	LUZERNE COUNTY		
Duryea	16	642	759,600
Edwardsville	7	151	175,200
Freeland	1	48	57,600
Hazleton	6	695	804,900
Luzerne	3	32	36,900
Nanticoke	21	661	750,600
Pittston	12	561	654,600
Plymouth	18	553	625,800
Swoyersville	5	238	268,800
West Hazleton	3	72	86,400
West Pittston	2	53	63,600
Wilkes-Barre	24	1,445	1,632,300
Total	118	5,151	5,916,300

CONTINUED

Table 9. — Continued

Unit area[1]	Sites	Area of sites	Trees required
	No.	*Acres*	*No.*
NORTHUMBERLAND COUNTY			
Mount Carmel	8	489	558,600
Shamokin	10	509	600,600
Trevorton	1	230	276,000
Total	19	1,228	1,435,000
SCHUYLKILL COUNTY			
Ashland	9	448	496,500
Frackville	2	132	155,400
Mahanoy City	8	296	339,900
McAdoo	2	67	80,400
Minersville	9	265	304,200
Pottsville	7	160	182,400
St. Clair	9	621	723,000
Shenandoah	12	885	1,019,100
Tamaqua	9	432	507,600
Tower City	1	38	45,600
Tremont	5	96	102,900
Total	73	3,440	3,957,000
SUSQUEHANNA COUNTY			
Carbondale	1	10	12,000
Total	1	10	12,000
Total, region	358	17,025	19,350,600

[1] Counties and unit areas with no cover plantings are not listed.

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Analyzing Uncertain Timber Investments

by Robert Marty

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Analyzing Uncertain Timber Investments

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The Uncertainty Problem[1]

THIS paper is addressed to those who are interested in analyzing timber acquisition, protection, and management projects from a financial point of view. Financial appraisals of proposed forestry projects are undertaken to assign a profit index to the project, based on estimates of project costs and returns. Profit estimates are used increasingly by both government and industry as one important basis for choosing among competing projects.

Unfortunately, analysis does not always provide an accurate estimate of a project's financial outcome. Available information, particularly about future yields and prices, is often too unreliable to provide anything more than a rather uncertain prediction.

The uncertainty problem is compounded by the way that most analyses are prepared. Often the analyst presents only a single estimate of profit — a best guess. This practice tends to obscure the degree of uncertainty associated with the project, and the investor is left without any way of appraising the reliability of the profit estimate.

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[1] This paper is based in part on a dissertation presented to the faculty of the Graduate School of Yale University in candidacy for the degree of Doctor of Philosophy in 1961.

Presented here is a method of analysis that makes use of multiple estimates of project profitability stemming from different assumptions about the true values of uncertain factors like yields and prices. The purpose of the analysis is to screen competing projects to eliminate those that can be proved to be unprofitable, or surely less profitable than some other, regardless of the assumptions made about the values of uncertain factors.

When there is relatively little uncertainty about the true values of profit determinants, this screening identifies a single, most profitable project by discarding all others. When uncertainty is more pervasive, the screening ends with several competing projects remaining, no one of which can be shown to be more profitable than the others in all possible circumstances. Only in this last case does uncertainty have any operative significance for choice.

The purpose of this screening is not to reduce uncertainty—that can be done only by obtaining better information—but rather to identify just how much operative uncertainty exists. When more than one project does remain, the final choice will still be uncertain, and a matter of judgment, based on the investor's attitude toward risk-taking and his personal prognosis of relevant future events. Sometimes a formal decision rule embodying these personal judgments is useful in making a final choice, and some of these are discussed briefly.

RECOGNIZING UNCERTAINTY IN ANALYSIS

Three Types of Investments

A timber-acquisition or management project eventually results in one particular financial outcome. But it is what can be determined about this outcome beforehand, when the investment is made, that is important in decision-making. Three classes of pre-knowledge about outcomes have been distinguished: certainty, risk, and uncertainty (Knight 1921).

An investment is classed as certain if it is known to lead to one specified outcome without any serious doubt, as many persons feel is the case with a U. S. Government savings bond for example. An investment is classed as a risk if it leads to one of several outcomes, each of which occurs with a known probability. Lotteries, games of chance, and insurance are based on probabilistic outcomes of this sort, but investments in production do not often fall in the risk class.

Uncertain investments may lead to any one of many different outcomes also, but in this case outcome probabilities are unknown. Uncertainty means not only that the investor is unsure of what the outcome of an investment will be, but also that he cannot objectively rank the possible outcomes on the basis of their likelihood. Most business investments tend to be uncertain, at least to some degree; and investments in timber are no exception.

An Example

A somewhat different method of analysis has been suggested for risky or uncertain investments than is usual for investments that fall into the certainty class (e.g., Chernoff and Moses 1959). A simple example will help to illustrate the differences in these two systems.

Perhaps the most frequent investment decision in timber management is whether to delay the harvest of a merchantable stand for an additional period of growth. If the stand is harvested, the owner in effect liquidates an investment in growing stock, receives its value in the market, and then must find new uses for this capital. If harvest is delayed, the growing-stock investment is maintained and earns a return related to the increase in stand value that occurs during the ensuing period. Suppose that a stand of timber has a present stumpage value of $3,000, and that 5 years hence it will have a value of $3,400. The owner will buy U. S. Series E Savings Bonds with his stumpage income whenever harvest occurs. Should harvest be delayed 5 years?

If the owner of this stand wishes to maximize his dollar income, if future rotations are not of interest to him, and if the land is not to be sold, then the answer depends on whether a $400 increase in stumpage value is more than the increase in bond value he might receive as an alternative. This problem of choice can be summarized as follows:

Alternate courses of action	*Outcome as measured by market value 5 years hence*
1. Delay harvest	$3,400
2. Harvest and buy bonds	3,585

Investments like this, with outcomes that are quite certain, can be analyzed in a straightforward manner that leads to unequivocal decisions. This stand should be harvested now because the bond alternative will produce close to $600 of income during the period as compared with the $400 that can be earned by delaying harvest.

Of course there is usually some question about future growth rates and market prices in a problem of this sort, and it is apparent that the outcome of delaying harvest will be contingent upon the growth rate and stumpage price that actually materialize. Also, delaying harvest means that the stand will be subject to fire, pest, and weather losses for another 5 years, which could endanger present volume as well as future growth.

On the bad side then, it is conceivable that the stand might be destroyed by fire, or that there might be a depressed market for stumpage 5 years hence. On the good side, it is possible that growth will be better than expected, or that stumpage prices will increase to such an extent, say, that the stand doubles in value during the period. So delaying harvest might result in a stand value in 5 years of anywhere between, say, $1,000 and $6,000. Thus, when the analyst wishes to recognize that outcomes are risky or uncertain, a different form of analysis is called for:

	Outcome as measured by market value 5 years hence		
	A	*B*	*C*
Alternate courses of action	*Poor prices or high losses (dollars)*	*Expected growth and prices (dollars)*	*Exceptional prices (dollars)*
1. Delay harvest	1,000-3,000	3,000-4,000	4,000-6,000
2. Harvest and buy bonds	3,585	3,585	3,585

The different sets of circumstances listed under A, B, and C embody different assumptions about losses, growth rates, and prices; and it is clear that the best choice between harvesting now and delaying harvest depends on which of these sets of circumstances most nearly mirrors the future. If A comes about, it would be best to harvest now; if C occurs, harvest should be delayed; and if B happens, the analysis does not indicate which alternative will be most profitable.

This analysis differs from the first one in that it considers several different assumptions about underlying circumstances. This is the way uncertainties about these determinants of profitability are introduced into the analysis. Notice that the analysis shifts the uncertainty from outcome to these underlying factors. The question is no longer what outcome will materialize, but which particular set of circumstances will come into being. The unique contribution of this form of analysis is that it shows exactly how outcomes are affected by changes in circumstance, relationships that the first analysis cannot disclose.

Another important difference is that this analysis will indicate when uncertainties are serious enough so that one cannot be sure which alternative will be best. In some cases one alternative will have a better outcome than others in all circumstances that it seems relevant to consider, while in other cases the alternative with the best outcome will change from one set of circumstances to the next. When the latter happens, as it does in the harvest-delay example, it is a signal that available information is too unreliable to allow any analysis to demonstrate that one alternative will surely be better than all the others. The decision-maker then has the choice of: (1) delaying the decision in hopes of obtaining better information; (2) obtaining a contract or agreement that reduces the uncertainty (for example, a forward pricing agreement); or (3) making an immediate judgment decision as best he can.

CHOOSING AMONG UNCERTAIN ALTERNATIVES

Some Criteria for Choice

Since a comparison of costs and returns does not always lead to a clear preference among alternatives when uncertainty is recognized, other decision tactics have been suggested. Most of these take the form of simple rules.

Several analysts have suggested decision tactics which insure against unwanted outcomes in choosing among investments with uncertain outcomes. Wald (1950) suggests choosing the alternative with the highest minimum outcome over all sets of circumstances considered. Savage (1951) has proposed that outcomes be replaced by "regret" values, which substitute for each outcome the amount that would have to be added to make each equal to the largest outcome of any alternative in that particular set of circumstances. Thus the highest outcome for alternatives in a particular set of circumstances is replaced by zero, and an outcome of 10 less than the highest is replaced by 10. These substituted values are taken as a measure of the loss or regret one would experience by choosing the wrong alternative; and Savage suggests choosing the alternative with the lowest maximum regret over all sets of circumstances considered.

These approaches are very conservative, because they both assume that the worst will happen. Hurwicz (1951) has developed a means of adjusting the choice criteria to reflect a more optimistic outlook. He asks the decision-maker to choose a number between zero (entirely optimistic) and unity (entirely pessimistic), which he terms a *pessimism index.* A weighted value is then computed for each alternative, made up of the product of the pessimism index and the minimum outcome for the alternative, plus the product of one minus the pessimism index and the maximum outcome. The alternative with the highest weighted value is then chosen. This criteria becomes equivalent to Wald's when the pessimism index is unity, but does take into account the best outcome as well for smaller index values. However, it still takes no account of sets of circumstances that give rise to intermediate outcome values.

The principle of insufficient reason, attributed to Laplace, can be used to take all circumstances and outcomes into consideration. This principle says that since there is no objective information about the relative likelihood of the various sets of circumstances, all should be treated as equally likely. One applies this criteria simply by averaging the outcomes for each alternative and choosing the one with the best average.

These four decision rules all assume that absolutely nothing is known about the relative probability of the various sets of circumstances considered. Savage (1954) has suggested a subjective probability theory to treat situations where, intuitively at least, some assumptions about uncertain factors seem more plausible than others. He suggests a method of transforming these opinions into a consistent subjective probability distribution for the sets of circumstances considered. The outcomes for each action are then weighted by the subjective probabilities associated with the corresponding circumstance sets, and these are summed to give a subjective expected value for the action or alternative. The alternative with the highest weighted value is selected.

When there are risk outcomes to deal with — that is, when the various possible outcomes and their underlying sets of circumstances have a known and objective probability distribution—then the most commonly suggested decision rule is to choose the project with the highest weighted average outcome — expected value, as it is termed. Since risk probabilities are objective, or what have been termed "actuarial certainties," the alternative with the highest expected value can really be said to have the best chance of being most profitable. This is in contrast to Savage's subjective probability approach, where no such interpretation would be valid.

All Choice Criteria Require or Assume That Outcome Probabilities Are Known

When the outcome of investment alternatives are certain, analysis leads to an unequivocal choice on the basis of outcome comparisons. When investments have risk outcomes, analysis provides an objective estimate of the alternative that is most likely to be most profitable. Highest expected value is not a perfect guide to choice, and it is not the only characteristic of importance in choosing among risk alternatives; but this criterion will lead to the right choice more frequently than any other.

When there is absolute uncertainty about outcomes — that is, when as far as is known one underlying set of circumstances is just as likely as any other — no particular choice criteria can be singled out as best. However, most of the criteria are logical only under a particular assumption about the likelihood of the various circumstances and their outcomes. It is logical for a decision-maker to use Wald's "maximin" criteria or Savage's "minimax regret" criteria only if he really believes that the worst outcome is the only one that has much chance of occurring. It is logical for him to use Laplace's "equal likelihood" criteria only if he really believes that all outcomes are equally likely, and so forth.

The various approaches to the problem of absolute uncertainty all point to the idea that the decision-maker must have some information or belief about the likelihood of various underlying circumstances and their outcomes if he is to have a logical preference for one decision rule over another. Savage has developed a system of making explicit an individual's subjective estimates of likelihood. Of course, when a complete likelihood distribution for the various sets of circumstances has been developed, one can dispense with special decision rules and use the more general notion of weighted average outcome as the basis for choice.

Perhaps the major point to be made here is that although one can develop a consistent, subjective probability distribution as the basis for applying the expected-value choice criteria, this simply throws the subjectivity back one more stage. Intstead of selecting a special choice criteria subjectively, one chooses likelihoods for the various outcomes subjectively and applies a general choice criterion. The expected value criterion is no more likely to lead to the best choice than any other when expected values are based on subjectively derived probability estimates.

USING ANALYSIS TO DISCARD ALTERNATIVES

All the foregoing decision rules attempt to single out the one best alternative. When there is a significant degree of uncertainty, this cannot be done without making assumptions about the probabilities of various circumstances and outcomes that may be untrue and so misleading. However, analysis can begin with the more limited objective of excluding clearly non-optional alternatives. It is possible to exclude alternatives that are not sufficiently profitable under any set of circumstances to interest the investor, to exclude alternatives that are less profitable than some other alternative in every circumstance, and to do this without reference to the probabilities of these circumstance sets. This initial screening may leave no acceptable alternatives, or only a single acceptable alternative, or several. In the first two cases analysis has shown the uncertainty to be negligible or unimportant. In the last case there is still a decision problem to be resolved, but analysis has simplified and clarified it as much as the available information allows.

When uncertainty is recognized, then, analysis may not always be able to identify the best alternative. Rather, analysis must be thought of as a means of excluding the worst alternatives. Thus, the analysis defines the amount of operative uncertainty in any decision situation by the number of alternatives that it cannot exclude. The analogy to the general scientific method is clear. The analyst hypothesizes that each alternative considered is both profitable and better than any of the others, and in the analysis he attempts to disprove this hypothesis for as many alternatives as he can.

The first task in any investment analysis is to formulate the investment problem. This is done by determining the investor's primary goal or objective, selecting a set of alternative investment possibilities that the investor can undertake in the near future with the investment resources at his command and that are relevant to his primary investment objective, and choosing a measure of economic efficiency, such as internal rate of return, benefit/cost, or present worth, as a basis for comparing alternatives. Further steps in the analysis of uncertain investments include (1) developing a system for predicting the outcome of each investment alternative under a variety of circumstances, (2) setting up formal comparisons of the investment alternatives and discarding those that are not sufficiently profitable or are non-optimal, and (3) posing a question of choice for the investor among the alternatives that are left. The remaining sections of this paper consider these analytical tasks in detail.

Analyzing Uncertain Investments

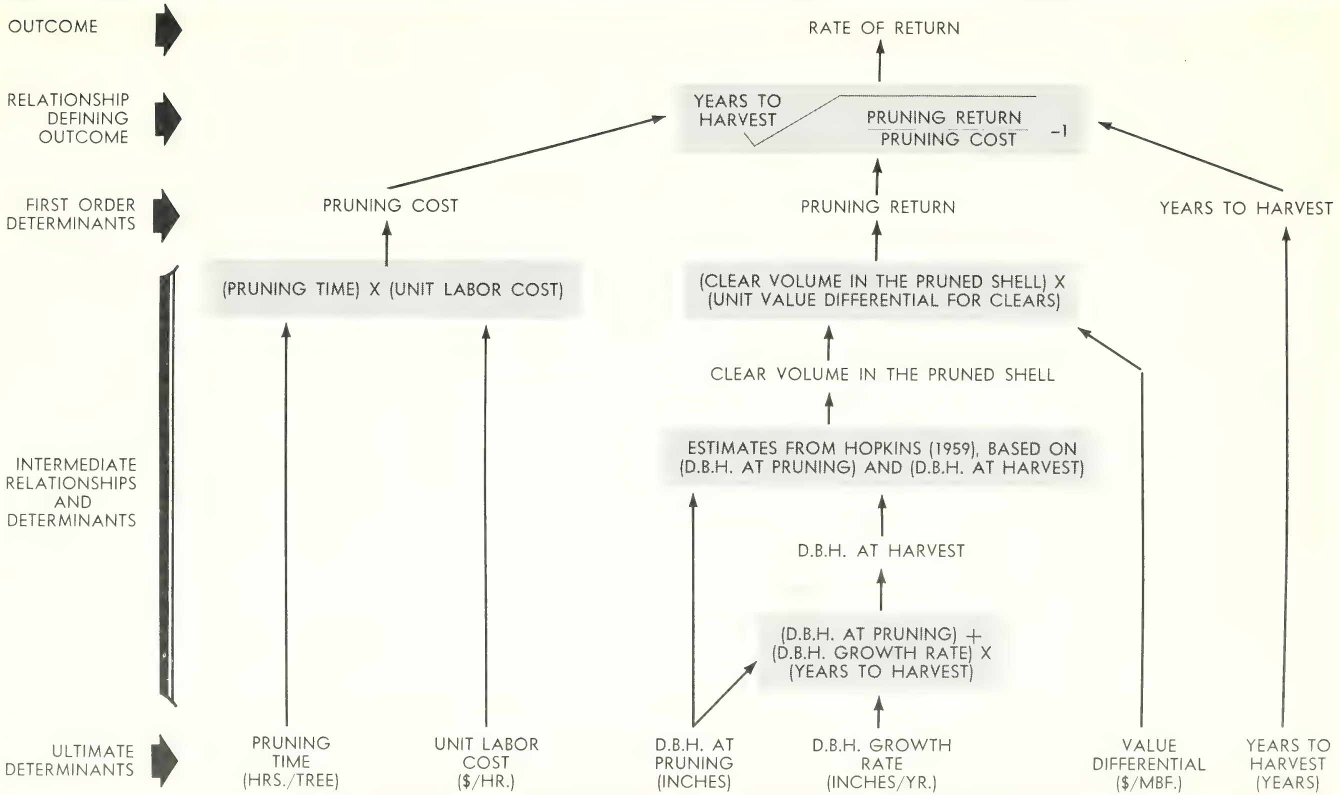
PREDICTING OUTCOMES FOR PROJECTS

Outcome Predictions Are Based on a System of Relationships

The economic outcome of an investment is determined by the costs it occasions and returns it generates. These costs and returns occur at different dates, but all can be brought for comparison to a common point in time with a compound-interest formula. The size of each cost or return is determined by a physical input or output and its unit value. Physical inputs indicate the cost of undertaking the investment in question in terms of man- and machine-hours and quantities of materials, while physical outputs indicate the yield response that is anticipated. These physical quantities and their unit values may be estimated directly or with the aid of empirical relationships. When a relationship is used, the physical quantity or unit value is itself determined by the values of the "independent variables" called for in the relationship. Outcome estimates, then, are built up from a series of interconnected relations. Once such a set of relations is constructed, the analyst can compute outcome by assigning values to each of the ultimate determinants of the system.

As an example, consider the outcome of pruning an eastern white pine crop tree. If butt-lot pruning is done in one stage there will be one cost at the time of pruning and a single return when the tree is harvested. When rate of return is chosen to measure outcome, then a system of relations for predicting the rate of return might be constructed as shown in figure 1. Notice that the system begins with a mathematical definition of rate of return

Figure 1. — The return to pruning white pine: an example of a system of relations defining investment outcome.


OUTCOME
RELATIONSHIP DEFINING OUTCOME
FIRST ORDER DETERMINANTS
INTERMEDIATE RELATIONSHIPS AND DETERMINANTS
ULTIMATE DETERMINANTS
RATE OF RETURN
YEARS TO HARVEST √(PRUNING RETURN / PRUNING COST) −1
PRUNING COST
PRUNING RETURN
YEARS TO HARVEST
(PRUNING TIME) X (UNIT LABOR COST)
(CLEAR VOLUME IN THE PRUNED SHELL) X (UNIT VALUE DIFFERENTIAL FOR CLEARS)
CLEAR VOLUME IN THE PRUNED SHELL
ESTIMATES FROM HOPKINS (1959), BASED ON (D.B.H. AT PRUNING) AND (D.B.H. AT HARVEST)
D.B.H. AT HARVEST
(D.B.H. AT PRUNING) + (D.B.H. GROWTH RATE) X (YEARS TO HARVEST)
PRUNING TIME (HRS./TREE)
UNIT LABOR COST ($/HR.)
D.B.H. AT PRUNING (INCHES)
D.B.H. GROWTH RATE (INCHES/YR.)
VALUE DIFFERENTIAL ($/MBF.)
YEARS TO HARVEST (YEARS)

that identifies its deterimants: cost, return, and investment period. Supporting empirical relationships are used to estimate these "first order" determinants, and so on until ultimate determinants are identified that must be measured or estimated directly.

In this example, if one uses $100 per 1,000 board feet for the added value of the clear volume in the pruned shell, 8 inches for the d.b.h. at pruning, 0.2 inches for annual rate of d.b.h. growth, 40 years to harvest, 1/6 hour for pruning time, and $1.50 per hour for labor cost, then the system estimates a rate of return to the investment of 7.9 percent. Other determinant values will produce other outcomes.

These estimates are subject to error if any costs or returns are left out of account, or if the empirical relationships included in the system are not exact; but this "model" error is usually small in comparison with the error associated with choosing correct values for determinants. The complexity and accuracy of the model can vary greatly, and they depend on the availability of information and on the analyst's skill in constructing models.

Ranges of Values for Uncertain Determinants

In the pruning example, it is apparent that current knowledge is not sufficient to be sure of what value every determinant should be assigned. The labor wage rate and tree d.b.h. at pruning would presumably be known without significant error. The other four elements are uncertain, at least to some degree. It is possible that pruning of the first log might take anywhere from 5 to 20 minutes (Ralston and Lemmien 1956; Meyer 1940; and Cline and Fletcher 1928). The d.b.h. growth rate might range anywhere from 1/20 to 1/5 inch per year, depending on site quality and competitive conditions. Years to harvest might be anything between 10 and 100; and the added value of clear volume, which at the mill level is now about $100 (Fedkiw et al. 1960) might range from zero, if clear volume is not valued in tomorrow's markets, to $200 if grade/price differentials broaden and most of this value is passed on to the producer in the form of increased stumpage prices.

After the outcome-predicting system is developed, the analyst must decide on the range in values he will consider for uncertain determinants. He can, more or less arbitrarily, drop from consideration some possible values for uncertain determinants. It seems most reasonable to drop the least likely values if any are to be dropped, and there is often an objective basis for believing that some values are less likely than others. To this extent the analyst does not often have to deal with absolute uncertainty. For example, a 5- to 20-minute time range for butt-log pruning has been observed in various cases, but in most studies butt logs took less than 10 minutes to prune. Times in excess of 10 minutes are less likely, perhaps considerably so. Ownership characteristics may allow the analyst to judge some rotation ages as quite unlikely in particular cases, and so forth.

The analyst may wish to reduce the range of determinant values he considers in this way, or he may feel that he must retain all possible values. The advantage of disregarding some of the least likely values is that this narrows the range of outcome for an investment alternative without a commensurate narrowing in the probability of having included the actual outcome. The danger in disregarding some values is simply that the outcome that will actually materialize may not be included in the predicted range. Sometimes analysts disregard all but one value for uncertain determinants and, in effect, analyze the investment as if its outcome were certain. This might be viewed as one extreme in treating uncertainty, while dealing with all possible determinant values is the other. It seems reasonable and useful to pursue a middle course by disregarding some of the least likely determinant values, when there is an objective and reasoned basis for identifying the values that are indeed least likely. However, it must be stressed that the discarding of determinant values is to some degree subjective, and the truncated ranges of outcome which result cannot be assigned an objective probability density.

COMPARING PROJECTS

Sensitivity Testing

After an outcome-predicting system is developed for each alternative, the next step is to test the system by determining how outcome changes when determinant values are changed. The analyst can judge the effect of each determinant in this way, and he may decide to simplify his prediction system by using a single arbitrary value for an uncertain determinant that changes outcome very little regardless of what value it is assigned within its range. This "sensitivity testing" should be an initial step in analyses of this sort. It requires that a sequence of outcome values be generated for each alternative.

Such a sequence is shown in table 1 for the pruning example. Notice that two or more determinant values are used to represent the range of each uncertain determinant. In this case outcome, measured by rate of return, varies significantly from one set of determinant values to another, indicating that none of the uncertain determinants have a negligible affect within their ranges; and so all determinants are retained. The essential test for each determinant is whether it changes outcome significantly when other determinants are held constant.

Table 1.—Rates of return to pruning[1] under various assumptions about the values of determining factors

Growth rate	Pruning time	Time to harvest	Additional value of clear volume, in dollars per M board feet— 50	100	150
Inches per year	*Minutes per tree*	*Years*	*Percent*	*Percent*	*Percent*
0.10	10	60	2.6	3.8	4.5
		50	1.4	2.8	3.9
	5	60	3.8	5.0	5.7
		50	2.8	4.2	5.1
0.15	10	60	4.4	5.7	6.4
		50	4.5	6.0	6.8
		40	3.9	5.7	6.8
	5	60	5.7	6.9	7.6
		50	6.0	7.4	8.3
		40	5.7	7.6	8.6
0.20	10	60	5.5	6.7	7.4
		50	5.8	7.3	8.2
		40	6.0	7.9	9.0
		30	5.2	7.7	9.1
	5	60	6.7	7.9	8.2
		50	7.3	8.8	9.7
		40	7.9	9.8	10.9
		30	7.7	10.2	11.7

[1] Assumes pruning of an 8-inch d.b.h. white pine when the labor wage rate is $1.50 per hour.

Independent Determinants and Project Comparisons

Although all uncertain determinants can be used to define sets of circumstances for explicit consideration — or "states" as they are sometimes termed — this is not always desirable. The purpose of considering individual sets of circumstances, or states, separately is to facilitate comparisons among the outcomes of the various alternatives. These within-state comparisons are most revealing when the determinant values defining each state must be the same regardless of what alternative is chosen.

This is true only for determinants with values that are not significantly influenced by the choice that is made among alternatives. Determinants reflecting market conditions, over which many stumpage producers have little or no control, are good examples of these "independent" determinants. For most producers, a particular system of stumpage prices will obtain at a given date regardless of what immediate choice among management programs he makes. Therefore it is not necessary to compare one program assuming a low unit stumpage price with a second alternative assuming that a high unit price will be paid. Whatever unit price is paid, it is likely to be the same regardless of the intermediate management alternative chosen.

Decisions about stand management that will be made in the future may also fall into this category of independent determinants. For example, although optimum economic rotation age differs according to how intensively a stand is managed (i.e., economic maturity is not independent of intermediate management), in many cases rotation ages are set without reference to value growth rates or other effects of past management. Determinants that relate to future management, then, may be independent enough of immediate management decisions so that comparisons assuming independence are likely to be valid.

A third class of determinants with values that are independent of the alternative selected are those that are unique to a single alternative. Not all investment alternatives have the same outcome determinants. In the example that compared harvest delay with bond purchase there were no determinants that were common to both alternatives, for instance. These unique determinants may also be used to define states of nature since their values cannot be influenced by the choice among alternatives.

When independent determinants are used to define states, the "dependent" determinants are left, and are free to assume any values within their ranges. So the outcome estimate for each set of circumstances will be a range of values rather than a point estimate if there are any dependent determinants. This is because the underlying circumstances are not completely defined in these cases. Some determining factors are left undefined because their values change from alternative to alternative.

An Example of Defining States and Comparing Projects

Consider the problem of deciding which of two neighboring pine trees is to be pruned. The first tree is now 10 inches d.b.h., while the second is an 8-inch tree. The unit cost of labor is $1.50 per hour. The four uncertain determinants are, again, the subsequent growth rate, the time required for pruning, years to harvest, and the added value of clear volume at harvest. In this case both alternatives have exactly the same outcome determinants. Two of these might be considered independent of the choice: years to harvest and the value differential. In even-aged management, each of these determinants will have the same value regardless of which tree is pruned.

The other two determinants, growth rate and pruning time, might have different values for each of the trees. Suppose that the analyst chooses to consider the following value ranges for these four determinants: years to harvest, 40 to 60; value differential, $50 to $150; growth rate, 0.15 to 0.20 inches per year; and pruning time, 5 to 7 minutes per tree. He sets up nine different states made up of different combinations of values for the two independent determinants, years to harvest and the value differential. He then computes a range of outcomes for each state determined by the extreme values for the dependent factors. The results are shown in table 2. Notice that regardless of the state that comes into existence, the return ranges for the two trees are very similar.

Consider a contrasting example where, again, two trees are compared for their return to pruning. In this case both trees are the same size, but one is expected to grow more rapidly than the other. The first tree is expected to grow on the average between 0.15 and 0.17 inches per year, while the second tree is expected to grow between 0.10 and 0.12 inches per year. Table 3 shows the results of this second comparison.

The analysis shows that the faster-growing tree will return more to pruning regardless of the state that obtains, and despite the considerable range in outcome that exists within states. Notice

Table 2.—Rate-of-return ranges for pruning two different sized white pine trees, in percent

Alternate courses of action considered	Added value of clear volume, dollars per M board feet —								
	$50 Years to harvest			$100 Years to harvest			$150 Years to harvest		
	40	50	60	40	50	60	40	50	60
Prune the 10-inch pine	4.9-8.1	5.4-7.5	5.2-7.2	6.8-10.0	6.8-9.0	6.5-8.5	7.8-11.1	7.7-9.9	7.2-9.2
Prune the 8-inch pine	4.8-7.9	5.2-7.3	5.1-6.7	6.7-9.8	6.7-8.8	6.3-7.9	7.7-10.9	7.6-9.7	7.0-8.2

Table 3.—Rate-of-return ranges for pruning two pine trees of different growth rates, in percent

Alternate courses of action considered	Value differential, dollars per M board feet —								
	$50 Years to harvest			$100 Years to harvest			$150 Years to harvest		
	40	50	60	40	50	60	40	50	60
Prune the fast-growing pine	4.3-6.3	4.9-6.3	4.8-5.9	6.2-8.2	6.4-7.7	6.0-7.1	7.2-9.3	7.2-8.6	6.7-7.9
Prune the slow-growing pine	0-3.4	2.3-4.5	3.8-4.7	0-5.2	3.9-6.9	4.4-6.9	0-6.7	4.8-6.2	5.1-6.7

that the entire range in outcome — the range over all states — is 0 to 6.7 percent for the slow-growing tree and 4.3 to 9.3 percent for the fast-growing tree. So if the analyst computed only these total ranges he could not assert that the faster-growing tree would surely have the better outcome, since these total ranges overlap. It is only because states defined by the independent determinants are used that comparisons show the operative uncertainty to be negligible.

Discarding Strongly Dominated and Unprofitable Alternatives

This last example demonstrates one extreme in outcome comparisons. If one alternative has an outcome range that is entirely below the outcome range of some other alternative in every set of circumstances considered, then it is said to be strongly dominated. Strongly dominated alternatives can be dropped from consideration by the analyst because they are certain to be less than optimal, within the range of conditions examined.

Unprofitable alternatives can also be weeded out at this point. In most situations there is a definite minimum rate of return that is required by the investor. The analyst can discard alternatives that do not reach this minimum in any state, as being not sufficiently profitable. For example, if the investor wished to make at least 7 percent on his pruning investments, the analyst could discard the slow-growing pine in table 3 as an alternative that was not sufficiently profitable, even if it had not been strongly dominated.

POSING THE QUESTION OF CHOICE

More than one alternative may remain after those that are not sufficiently profitable or that are strongly dominated by others have been eliminated. In these cases there is a problem of choice that the analyst cannot resolve, because he does not possess sufficient information.

These remaining alternatives may be characterized by outcomes of various sorts. At one extreme are the more certain alternatives whose outcomes do not change much from state to state. Other alternatives may have outcomes that vary markedly from one state to the next, moving from heavy losses to large gains. The harvest-delay example contrasted a very certain alternative with one that was rather uncertain, and the contrast is sharp. The first pruning example (table 2) portrays another type of comparison. Here both alternatives, pruning the 8-inch tree and pruning the 10-inch tree, had nearly identical outcomes in all sets of circumstances considered.

When alternatives have overlapping outcome ranges in all states considered, the analysis provides little basis for choosing among them. When the contrasts among outcomes are sharp enough so that one alternative strongly dominates others in at least some states, the analysis does provide some basis for preferring one above the others.

The investor's preference in these cases will depend basically on how he views a rather uncertain alternative as opposed to one that is less uncertain, or on whether or not he has any strong convictions about the likelihood of various states. If he believes that one or more of the states are more likely than the rest, he will probably prefer the alternative that has the better outcome range in these states. If he has no particular feeling about the probability of various states, he may want to make the choice on the basis of performance over all states. Quite commonly this comes down to choosing between a safe alternative with a rather modest return and an uncertain alternative that combines lower returns or even losses in some states with the chance of exceptional gains in others. His choice in such cases will depend on his reactions toward risk-taking.

The analyst's final task is to present the results of his analysis so that these aspects are brought forward and made as clear as possible. In making the final choice among the remaining alternatives, it may sometimes be appropriate to suggest one of the formal criteria for choice discussed on pages 6-8.

Summary

The system of analysis presented here is designed to simplify the choice among investments without ignoring the uncertainties involved in predicting their outcomes. The analysis proceeds by discarding investments that are clearly less rewarding than others despite outcome uncertainty, and those that are not sufficiently profitable under any of the sets of circumstances considered to interest the investor.

When outcome uncertainty is slight, the analysis will discard all alternatives but one. When uncertainty is more pervasive, several alternatives will remain; and the analysis will have defined an area for subjective judgment by the investor.

There is no analytical technique that can validly remove the uncertainty about which of the remaining alternatives is best. That can be done only by obtaining better and more complete information. One advantage of this system of analysis is that it goes only as far toward a final solution as available information justifies.

This system of analysis is not easy to apply. It requires repeated estimates of outcome, assuming many differing sets of conditions; and it calls for comparisons among alternatives, which are not always easy to construct. Therefore, uncertainty analysis should not be undertaken casually or applied to problems of minor importance. It does seem to provide a useful middle ground between perfect-knowledge analyses based on a single set of assumptions about determinant values, and completely subjective choices, when the problem of choice is important enough to warrant the necessary analytical costs.

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FOREST SERVICE
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by Thomas W. McConkey

Direct Seeding of Pine and Spruce in Southwestern Maine

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1964

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

Direct Seeding of Pine and Spruce in Southwestern Maine

■

The Author . . .

THOMAS W. McCONKEY took his bachelor's and master's degrees in forestry at Cornell University in 1933 and joined the U. S. Forest Service the same year. His research work has been almost entirely in the fields of timber management and silviculture. His interest in white pine silviculture dates from 1947, when the Northeastern Forest Experiment Station assigned him as forester in charge of its Massabesic Experimental Forest at Alfred, Maine.

Introduction

WHEN lands suitable for growing pine or other softwood species are burned in New England, direct seeding is frequently mentioned as a possible means of establishing desirable new stands over large areas. Closely related to this are the possibilities of converting abandoned farm lands or areas occupied by scrub growth to productive forest stands.

Interest in direct seeding in New England has been shown as early as 1925. At that time Baldwin[1] started a series of spot seeding tests, which extended over a 14-year period. Although he had some successes in these tests, he considered results too uncertain to recommend use on a large scale. Results of direct-seeding trials begun in the Lake States in 1926, using some of the species frequently planted in New England, were not successful with these species.[2] However, fairly effective chemicals for protecting seed from birds and rodents have been discovered during the past decade, and successful direct-seeding techniques now have been developed in other regions. Possibly these techniques can also be used in New England, with some modifications.

In guidelines prepared for direct seeding loblolly pine, Mann and Derr[3] emphasized the importance of selecting sites suitable for the desired species and of preparing suitable seedbeds. Both Baldwin and Shirley also recognized the importance of these factors.

In view of this continued emphasis on site and seedbed, a direct-seeding study involving five species on two sites was begun in the fall of 1958 in southwestern Maine. The intent was to gather some preliminary information, by species, about the influence of soil type and seedbed-preparation measures on initial seedling establishment.

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[1] Baldwin, H. I. DIRECT-SEEDING EXPERIMENTS. N. H. Forestry and Recreation Dept. Fox Forest Notes No. 14, 1 pp., 1939.

[2] Shirley, Hardy L. DIRECT SEEDING IN THE LAKE STATES. Jour. Forestry 35: 379-387, 1937.

[3] Mann, W. F. Jr., and H. J. Derr, GUIDELINES FOR DIRECT-SEEDING LOBLOLLY PINE. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 188, 23 pp., illus., 1961.

The Study

Five species, four of them commonly planted in the Northeast, were selected for this test: Norway spruce *(Picea abies* L.), white spruce *(Picea glauca* (Moench) Voss), red pine *(Pinus resinosa* Ait.), pitch pine *(Pinus rigida* Mill.), and white pine *(Pinus strobus* L.).

Plots were established at two locations representing distinct differences in site on land that had been burned over by a forest fire in May 1957. The poorer site — an Adams loamy sand — has very little organic matter in the 3-inch layer of topsoil. The texture changes with depth from loamy sand at the surface to coarse loamy sand, and then to medium sand. This soil is excessively drained and is as poor as any in the general area. The soil of the better site — a Gloucester stony sandy loam — is well-drained and has good moisture-holding capacity. Organic matter is well distributed throughout the upper soil layers.

A split-plot design was used for the study. Four main plots, each containing 12 subplots, were established on each area. The subplots were 3 by 4 feet in size; each provided space for five 1-foot-square seed spots — one spot for each of the five species. Two of the main plots were randomly selected for the 1958-59 fall and spring sowing; the other two were used for the 1959-60 fall and spring series.

Three seedbed-preparation measures, two degrees of shading, and two seasons of sowing — a total of 12 subtreatment combinations — were assigned at random to the 12 subplots within each main plot. The three seedbed-preparation measures were:

1. Check (no treatment) — vegetation was mowed but soil surface was left undisturbed.
2. Roughen — sod was cut and turned over, which left an uneven surface full of small roots.
3. Scalp—sod was removed together with the adhering soil.

Shading was provided by Lumite Saran shade cloth of 52 percent density; this was supported over the appropriate plots by shallow boxes made of $\frac{1}{2}$-inch wire mesh. The two shade treatments were:

1. Check — no shade or box.
2. Shade — subplots were covered with box and shade cloth.

The third variable — season — was represented simply by fall and spring sowings.

Seeds of white spruce, pitch pine, and white pine were stratified for spring sowing, following recommendations of the Woody Plant Seed Manual. All seeds were treated with the Arasan-Endrin bird and rodent repellent developed by the U. S. Fish and Wildlife Service. One hundred seeds of each species were sown on a 1-foot-square spot on the 3- by 4-foot subplot; seeds were covered with about $\frac{1}{4}$ inch of soil. Wire mesh boxes, without the shade cloth, were installed at the time of seeding over all subplots that were to be shaded. Cloth was placed over all boxes at the time of spring seeding in April. Because the unshaded plots were not protected with wire mesh boxes, some seed loss could have occurred due to birds and rodents; however, such losses appeared to be relatively unimportant.

Germination and seedling mortality were tallied periodically for each series of seedings from May through the first summer.

Rainfall and temperature records for the general locality were available from a fire-danger station maintained by the Maine Forest Service. Plot data on such factors as soil moisture and soil temperature were not obtained. Hence all subsequent references to these factors are based only on general observations and inference.

The effects of the different variables on germination and first-year seedling establishment were analyzed for individual species by split-plot analyses of variance. The main-plot factors were site and year of germination (fall-spring series). The subplot factors or treatments were season of sowing, seedbed preparation, and shading. Because the data were in percents, they were transformed for purposes of analysis by the arc-sine transformation.

Because of considerable variation in the quality and viability of the seed, it was impossible to tell whether or not the differences in behavior among species were attributable to true species differences. Therefore, species were not included in the analyses. However, gross differences among species are noted in discussing the results.

Results and Discussion

Seed germination tests were made, but results were erratic, generally averaging lower than the germination observed in the field. For example, the average of four tests of white pine was 23 percent, whereas the average field germination on scalped shaded plots was 56 percent. Therefore we made no use of the germination test results.

Norway spruce was particularly erratic, both in the germination tests and in germination observed in the field: in both situations germination ran much lower than that of the other species. Seedlings that did start on the plots seemed poorly adapted to cope with the rigors of field environment as exemplified by study conditions. Because of its erratic and generally poor performance, Norway spruce is omitted from the data summaries and analyses.

Effect of Cultivation and Shade

Both removal of the competing vegetation and shading resulted in marked increases in germination of all species on both soil types, regardless of sowing season or year when seeds germinated (tables 1 and 2). The increases were greater on the excessively drained Adams soil. Shading here and, to a lesser extent, removal of competing vegetation presumably increased length of time the soil surface was relatively moist during the critical germination period. Only pitch pine showed any appreciable germination on this site when no improvement measures were applied (table 1).

More seeds germinated on the scalped plots than on the roughened ones. The turned-over sods of the roughened plots were relatively loose, and the protruding brush-like roots would have facilitated water percolation. Consequently, the sods probably dried out faster than the smooth, scalped soil surfaces; and fewer seeds would have been in firm contact with moist soil at critical times.

As might logically be expected, more seedlings became established under the same conditions that were associated with better seed germination (table 1); and in the statistical appraisals both cultivation and shade generally were highly significant factors in establishment as well as in germination (table 3 vs. table 2). Even so, there was considerable variation in mortality among species

Table 1.—Percent of sown seeds that germinated and that produced established seedlings, by species, site, seedbed, and shading treatment (seasons and years combined)

Seedbed treatment	Shade treatment	Pitch pine		Red pine		White pine		White spruce	
		Germinated	Established	Germinated	Established	Germinated	Established	Germinated	Established
ADAMS SOIL									
None	None	17	14	4	2	3	2	2	0
	Shaded	40	28	22	7	16	12	19	5
Roughened	None	30	27	13	9	9	6	5	2
	Shaded	60	51	45	35	25	20	26	11
Scalped	None	49	46	25	20	26	21	18	14
	Shaded	71	68	60	53	48	45	42	33
GLOUCESTER SOIL									
None	None	36	26	22	11	27	21	9	1
	Shaded	49	27	39	19	40	35	25	10
Roughened	None	36	32	17	10	11	6	10	4
	Shaded	54	47	46	33	45	36	28	11
Scalped	None	53	48	37	33	27	19	23	7
	Shaded	67	58	52	47	64	57	39	25

Table 2.—Analysis of variance for germination of each species

Source of variation	Degrees of freedom	Pitch pine		Red pine		White pine		White spruce	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F
Main plots:									
Site (Si)	1	274	4.6	778	*9.6	2,739	**152.2	232	2.0
Year (Y)	1	3,113	**51.9	5	—	242	*13.4	1,437	*13.4
Si x Y	1	345	5.8	75	—	369	*20.5	288	2.5
Main plot error	4	60	—	81	—	18	—	116	—
Subplots:									
Season (Se)	1	514	**7.9	989	**11.8	549	*3.6	0	—
Cultivation (C)	2	2,009	**30.9	2,231	**26.6	2,321	**15.2	1,714	**5.7
Shade (Sh)	1	4,338	**66.7	7,717	**91.9	6,717	**43.9	6,462	**323.1
Si x Se	1	0	—	145	1.7	95	—	15	—
Si x C	2	264	*4.1	385	*4.6	533	*3.5	71	*3.6
Si x Sh	1	342	*5.3	104	1.2	63	—	120	*6.0
Y x Se	1	11	—	4,650	**55.4	1,921	**12.6	2,013	**100.7
Y x C	2	174	2.7	74	—	57	—	172	**8.6
Y x Sh	1	50	—	99	1.2	122	—	1	—
Se x C	2	222	*3.4	898	**10.7	412	2.7	177	**8.9
Se x Sh	1	84	1.3	457	*5.4	5	—	252	**12.6
C x Sh	2	43	—	78	—	109	—	927	**45.4
Subplot error	71	65	—	84	—	153	—	20	—

* Significant at 5-percent level.

** Significant at 1-percent level.

Table 3.—Analysis of variance for seedling establishment of each species[1]

Source of variation	Degrees of freedom	Pitch pine		Red pine		White pine	
		Mean square	F	Mean square	F	Mean square	F
Main plots							
Site (Si)	1	351	—	1,227	2.6	152	—
Year (Y)	1	468	—	222	—	1,389	**49.1
Si x Y	1	3,753	5.1	5,619	*11.7	878	3.1
Main plot error	4	732	—	480	—	283	—
Subplots:							
Season (Se)	1	1,106	**8.3	3,538	**27.4	5,765	**77.9
Cultivation (C)	2	1,911	**14.3	9,668	**74.9	2,064	**27.9
Shade (Sh)	1	520	3.9	1,477	**11.4	9,590	**129.6
Si x Se	1	1,004	**7.5	33	—	1,154	**15.6
Si x C	2	355	2.6	792	**6.1	625	**8.4
Si x Sh	1	35	—	734	*5.7	2	—
Y x Se	1	93	—	1,536	**11.9	17,403	**235.2
Y x C	2	166	1.2	1,001	**7.8	760	**10.3
Y x Sh	1	179	1.3	11	—	0	—
Se x C	2	367	2.7	2,756	**21.4	1,892	**25.6
Se x Sh	1	75	—	49	—	3,498	**47.3
C x Sh	2	249	1.9	5,548	**43.0	1,092	**14.8
Subplot error	71	134	—	129	—	74	—

[1] Establishment as a percent of seeds germinated. Data for white spruce insufficient for analysis.

* Significant at 5-percent level.

** Significant at 1-percent level.

and treatments (tables 1 and 4). For unknown reasons, more pitch pine died on the shaded plots than on the unshaded ones. Mortality percents on untreated seedbeds generally were higher than on prepared ones, which simply affirms that competing vegetation is an unfavorable factor for both germination and survival after germination.

The combination of low germination and subsequent high mortality in white spruce so reduced the numbers of seedlings that a statistical analysis of establishment of this species could not be very meaningful. Therefore white spruce was not included in table 3.

Table 4.—Percent of seedlings lost during the first season by species, site, and treatment[1] (seasons and years combined)

Seedbed treatment	Shade treatment	Pitch pine	Red pine	White pine	White spruce
ADAMS SOIL					
None	None	16	—	—	—
	Shaded	29	67	25	74
	Both	25	—	—	—
Roughened	None	8	—	—	—
	Shaded	16	22	20	59
	Both	13	—	—	—
Scalped	None	6	20	19	22
	Shaded	4	12	6	22
	Both	5	14	11	22
GLOUCESTER SOIL					
None	None	28	51	22	—
	Shaded	46[2]	51	15	62
	Both	38	51	18	—
Roughened	None	10	42	—	—
	Shaded	13	27	21	61
	Both	12	31	—	—
Scalped	None	10	12	31	68
	Shaded	14	10	11	36
	Both	12	10	17	48

[1] Losses shown only where 15 percent or more of the seeds had germinated.

[2] This figure includes losses caused by intensive insect feeding on one plot.

Effects of Site

Germination tended to be higher on the better Gloucester soil than on the poorer Adams soil, but the differences were significant only for white pine and red pine (table 2). However, the interaction of site and cultivation was significant for the three pines and white spruce: scalping, as compared with no seedbed preparation, resulted in greater increases on the Adams soil than on the Gloucester.

On unshaded plots, germination was consistently higher on the Gloucester soil than on the Adams; on shaded plots, soil had less effect (table 1). The interaction of site and shade was significant only for pitch pine and white spruce: like scalping, shade resulted in greater increases on the Adams soil than on the Gloucester.

Site alone did not play a significant part in seedling establishment of any species (table 3). The interaction of site and cultivation was highly significant for both white and red pines but not for pitch pine; the direction of these interactions was the same for seeding establishment as for germination — greater effects on the Adams soil. A significant site-shade interaction occurred only with red pine.

Sowing Season and Year of Germination

Sowing season was a significant or highly significant factor affecting germination of the three pine species, and year of germination was significant or highly significant for all species except red pine (table 2). The effect of season was not consistent among species and years (table 5). For both years combined, spring was

Table 5.—Germination percent by sowing season and year of germination

Sowing season	Pitch pine		Red pine		White pine		White spruce	
	1959	1960	1959	1960	1959	1960	1959	1960
Fall	35	51	16	36	27	34	10	28
Spring	42	60	47	28	35	18	22	20
Both	39	56	32	32	31	26	16	24

the better time for pitch pine, red pine, and white spruce; fall was a little better for white pine. The effect of year of germination also was inconsistent. For the two sowing seasons combined, 1960 was the better year for pitch pine and white spruce; 1959 was better for white pine; neither year was better than the other for red pine.

These inconsistencies mean interactions in a statistical sense. In all species except pitch pine, the interactions between season and year were highly significant for both germination and first-year establishment (tables 2 and 3). The direction of these interactions in germination can be seen in table 5: spring sowing was better than fall sowing in 1959, and fall sowing was better than spring sowing in 1960. The pattern was similar for first-year establishment.

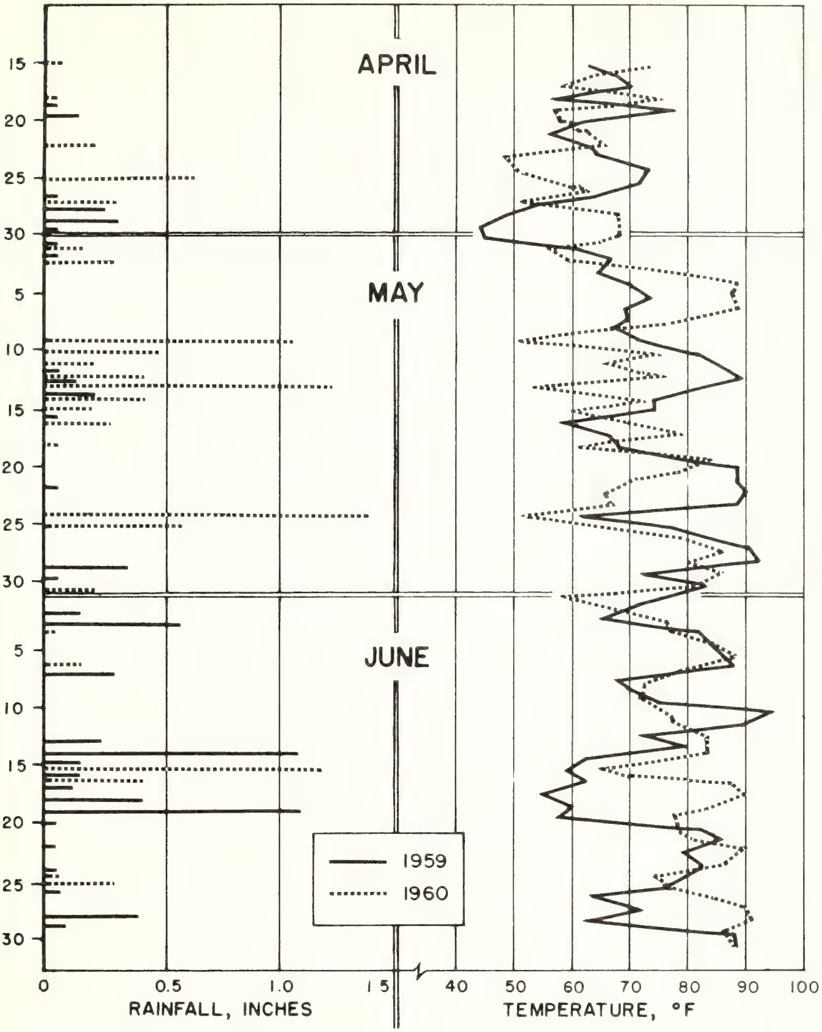
Little biological significance can be attached to these differences between seasons of sowing other than the observation that response to season may differ from year to year, presumably because of different weather conditions during the spring germination period. Thus the limited data from this study do not point to any one season as best for sowing.

Rainfall and temperature patterns during spring and early summer of the 2 years of the study no doubt account for at least some of the differences in germination and establishment. Records of rainfall and maximum daily temperatures at the nearby Maine

Table 6.—Average rainfall and maximum temperatures

Period covered	Days in period	Rainfall		Maximum temp.	
		1959	1960	1959	1960
		Inches	*Inches*	°*F.*	°*F.*
May 9 - 16	8	0.4	4.3	77	66
May 17 - 23	7	.0	.0	82	72
May 24 - 25	2	.0	2.0	70	66
May 26 - June 12	18	1.4	.3	80	78
June 13 - 16	4	1.5	1.6	66	78
June 17 - 20	4	1.9	.0	63	83
June 21 - 30	10	.7	.3	78	84

Figure 1.—Record of daily maximum temperatures and rainfall for 1959 and 1960.



Forest Service fire-danger station at Alfred are shown for the 2 years in figure 1. Although the weather was much the same both years until early May, the patterns were quite different later; and May 1959 was appreciably dryer and warmer than May 1960 (table 6).

According to records in another study and general observations, early May is the season when the main surge of seed germination normally occurs. For instance, in a seeding study made in 1962 with white pine, most of the seed had germinated during a 2-week period immediately after an early May rainfall pattern similar to that of May 1960.

Several general observations of sowing season and weather effects, and of species differences, are noted below:

Fall-sown seed germinated earlier than spring-sown seed.

In the dry spring of 1959, total germination tended to be lower for fall-sown seed than for spring-sown seed; in the wetter spring of 1960, this sowing-season relationship tended to be reversed.

Germination began earlier and ended earlier for pitch pine than for the other pines. Under the 1959 conditions of a dry May followed by a moist June, red and white pine germination continued through June and into July to a considerably greater degree than did pitch pine germination. The pattern of white spruce germination roughly paralleled that of pitch pine.

Red pine and white pine seemed somewhat more exacting in moisture requirements for germination than pitch pine.

Germination of all species tended to be later on untreated plots than on cultivated plots.

Summary

A direct seeding test was conducted in southwestern Maine to investigate the effects of seedbed preparation and shade on germination and first-year establishment of five conifer species: pitch pine, red pine, white pine, white spruce, and Norway spruce. The test involved the following variables: two sites — an excessively-drained loamy sand and a well-drained sandy loam; three seedbed treatments — scalped, roughened, and untreated check; two light intensities — shade and no shade; and two seasons of sowing — fall and spring — repeated through 2 years. The experimental unit for each species under each combination of conditions was a 1-foot-square spot on which 100 repellent-treated seeds were sown.

Norway spruce failed almost completely. For the other species,

both germination and establishment were consistently best on scalped, shaded plots. Here 45 to 68 percent of the pine seeds produced seedlings that were still alive at the end of the first growing season; comparable figures for white spruce were 25 to 33 percent. Roughened seedbeds were better than seedbeds with no treatment, but markedly inferior to scalped ones.

The main effect of site alone was not statistically significant in terms of first-year establishment, and it was significant for germination in only two species. However, various site-treatment interactions were significant. In general, seedbed preparation and shading were much more beneficial on the excessively-drained loamy sand than on the sandy loam.

Season of sowing was a statistically significant factor in both germination and first-year establishment, but the effects were not consistent among the four species analyzed; and there were various interactions with year and the other variables that, although statistically significant, probably meant little biologically.

■

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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

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The Penobscot Management-Intensity Demonstration Plots

An evaluation, after 9 years, of four different treatments and their effects on growth and development of mixed softwood stands in Maine.

by Arthur C. Hart

The Author —

ARTHUR C. HART, *research forester, has spent most of his professional career in the spruce-fir region of the Northeast. After taking his Bachelor's degree in forestry at the University of Connecticut in 1936 and his Master's at the Yale School of Forestry in 1938, he joined the Northeastern Forest Experiment Station and did research work at Alfred, Maine, and the Gale River Experimental Forest at Bethlehem, N. H. He left Federal service in 1941 to become manager for the Great Mt. Forest at Norfolk, Conn.; then served as senior forester with the Rubber Development Corporation in Brazil, and later with the Corps of Engineers in Costa Rica. Hart returned to the Northeastern Station in 1946. Since then he has been engaged in research in the spruce-fir type at the Gale River Forest and at the Station's research unit at Bangor, Maine. At present he is project leader in timber-management research at the Station's unit in Orono, Maine.*

The Penobscot Management-Intensity Demonstration Plots

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Introduction

WHEN the U. S. Forest Service published its *Reappraisal of the forest situation in the United States*[1] in 1948, it described the cutting practices of the period and divided them into five broad classifications: high-order, good, fair, poor, or destructive. This concept of cutting-practice levels was further elaborated in the *1948 Annual Report* of the Northeastern Forest Experiment Station.[2]

Shortly after this, the Penobscot Experimental Forest was established near Bangor, Maine; and one of the first research activities there was to plan and install a demonstration of four of these five cutting practices (the destructive cutting practice was omitted) in a form adapted to the local spruce-fir forest type. The objectives were threefold:

- To provide examples of well-defined cutting practices as an aid to forest owners and managers in deciding upon the level of management appropriate for holdings under their control.
- To give the Northeastern Station's spruce-fir management staff some practical experience in applying their knowledge and ideas of desirable silvicultural treatments to spruce-fir stands, and to train them for subsequent research on the Experimental Forest.
- To get preliminary cost-and-return data for the different management levels.

The effects of several cuttings upon the growth and development of the reserved stands — measured 9 years after the demonstrations were established — are reported in this paper. (On one demonstration plot a cutting was made 10 years after establishment, and the stand changes that resulted are noted.)

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[1] United States Forest Service. FORESTS AND NATIONAL PROSPERITY. A REAPPRAISAL OF THE FOREST SITUATION IN THE UNITED STATES. U. S. Dept. Agr. Misc. Pub. 668, pp. 46-49. 1946.

[2] Northeastern Forest Experiment Station. ANNUAL REPORT, 1948. U. S. Forest Serv. Northeast. Forest Expt. Sta., pp. 6-12. 1949.

The Demonstration Area

The demonstration area is a square 40-acre block of second-growth softwood timber located about ⅛ mile north of the Experimental Forest headquarters. The area was divided into four square 10-acre plots, and one cutting practice was assigned to each plot (fig. 1). Four soil types are represented here: Plaisted stony loam, Dixmont stony loam, Dixmont-Monarda very stony loam, and Burnham-Monarda stony loam. Although the proportions vary

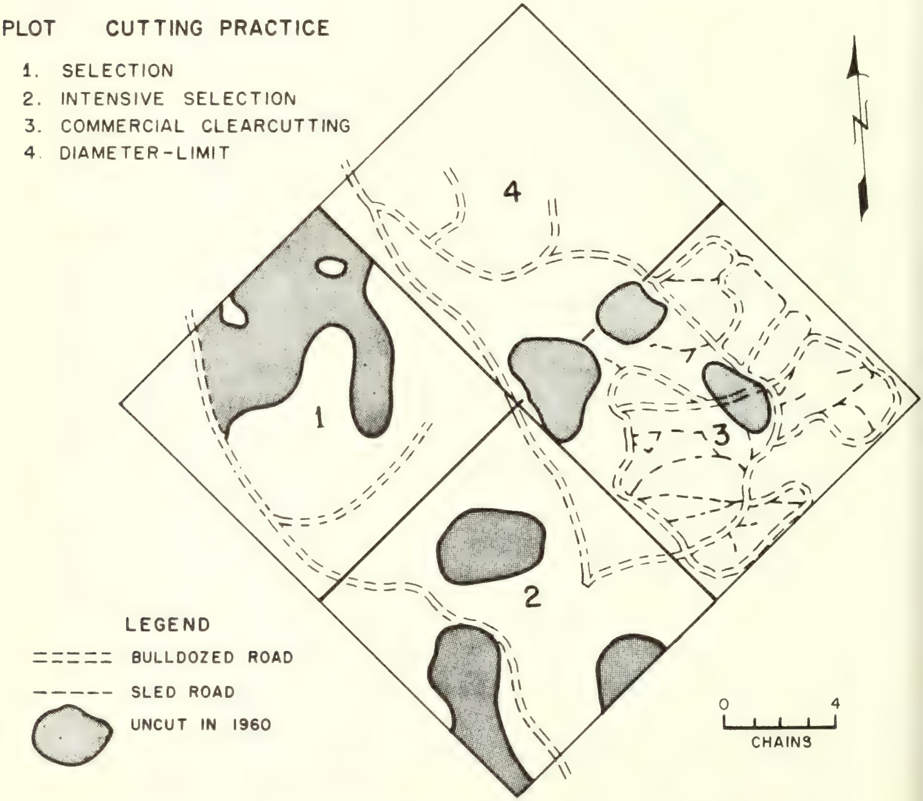

Figure 1. — The plots established on the Penobscot Experimental Forest near Bangor, Maine, to demonstrate four different management intensities.

from plot to plot, approximately half of the soils are well-drained and half are poorly to very poorly drained.[3]

The softwood stand on the area was composed primarily of spruce *(Picea rubens, P. glauca,* and *P. mariana),* balsam fir *(Abies balsamea),* and eastern hemlock *(Tsuga canadensis),* with an admixture of hardwoods, northern white-cedar *(Thuja occidentalis),* and eastern white pine *(Pinus strobus).*

The stand was more or less uneven-aged. Hemlock ranged up to 160 years in 1950, and most of the other species ranged from 50 to 65 years. The area had not been cut over for pulpwood, but during the past 200 years it had been high-graded for sawlogs from time to time.

Methods

INVENTORY

A 100-percent inventory of all living trees in the 5-inch (d.b.h.) class and larger was made, by 1-inch diameter classes and by species on each of the four plots. Trees below the 5-inch class were tallied in a 2-percent sample comprising two strips across each plot. In this sample, trees were recorded by 1-inch diameter classes by species, starting with the 1-inch class. A reproduction tally also was made along these strips, using the stocked-quadrat method, on 40 milacres in each plot.

Four such inventories were made: one in February 1950, before cutting; one in the fall of 1951, after cutting; one in January 1955; and one in August 1959. In the 1955 and 1959 inventories, trees that had died since the previous inventory were also recorded.

TREATMENTS

The poor, fair, good, and high-order cutting-practice levels, as defined originally in 1948, may be summarized briefly as follows:

> **Poor cutting** leaves the land with limited means for natural reproduction. This practice often causes deterioration of species composition and consequent reduction in both quality and quantity of forest growth.
>
> **Fair cutting** marks the beginning of cutting practices that will maintain on the land a reasonable stock of growing timber in species that are desirable and merchantable.
>
> **Good cutting** is based on good silviculture; it leaves the land in possession of desirable species in condition for vigorous growth in the immediate future.

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[3] Proportions of well-drained soils by plots are: Plot 1 — 75 percent, Plot 2 — 25 percent, Plot 3 — 40 percent, and Plot 4 — 56 percent.

High-order cutting is the type of harvest cutting that, in the forester's judgment, will best maintain quality and quantity yields consistent with the full productive capacity of the land.

In both good and high-order cutting practices, cultural measures of an investment nature are used where needed. High-order practices imply use of more intensive cultural measures than good practices.

Because the original terms carried connotations of prejudgment, the former cutting-practice levels are now referred to as *management intensities;* and poor, fair, good, and high-order cuttings are now more objectively and descriptively designated as *commercial clearcutting, diameter-limit cutting, selection cutting,* and *intensive selection cutting,* respectively. These four management intensities, as applied in the Penobscot demonstration plots, are described as follows:

Commercial clearcutting removes all the merchantable trees in one operation, leaving scattered unmerchantable trees of poor vigor, low quality, and undesirable species. No stand-improvement measures are applied, and the area is cut again when it becomes operable for pulpwood.

Diameter-limit cutting removes all merchantable trees above specified diameter limits and retains all trees below those limits. It also retains all trees of species that currently are non-commercial, and all culls regardless of size. No stand-improvement measures are applied. The area is cut again when it becomes operable for pulpwood under the same cutting rules. In our demonstration plot, all merchantable trees were cut, down to and including the following d.b.h. limits: spruce and hemlock — 10 inches; white birch and beech — 8 inches; and balsam fir and red maple — 6 inches.

Selection cutting is based on marking and removing mature trees and trees in all size classes that are defective, slow-growing, or otherwise unpromising for future timber production. The cutting cycle is 15 years. A limited amount of stand-improvement work is done.

Intensive selection cutting is based on the same principles as selection cutting, but it includes more intensive stand-improvement measures, and the cutting cycle is 5 years. Hence, stands are up-graded more rapidly and to a higher degree.

LOGGING OPERATIONS

First Cutting 1950 (All Plots)

A crew of four to six men, using hand tools, and with occasional help from one-man chainsaws, felled and sap-peeled the trees during the summer. On three plots (all except the clearcutting), where the cutting method specified skidding in tree lengths to bucking yards, the skidding was done in the fall, with horses. Chainsaws were used for most of the bucking. A D-4 tractor with bulldozer was used to prepare winter haul roads. On the clearcut plot, the bulldozer was also used to clear pathways for truck access to about 80 percent of the piled wood so that a minimum of sledding would be required.

Table 1. — Per cord costs and returns for four methods of cutting, 1950

Item	Intensive-selection	Selection	Diameter-limit	Commercial clearcutting
		Man-hours		
Fell-limb-peel	5.60	5.18	7.09	(1)
Skid-buck-pile	4.90	5.23	5.90	(1)
Total	10.50	10.41	12.99	10.91
		Dollars[2]		
Fell-limb-peel	5.16	5.01	6.58	(1)
Skid-buck-pile	4.69	5.01	5.65	(1)
Total	9.85	10.02	12.23	10.83
Horse	.18	.16	.17	—
Reyarding	—	—	—	.80
Tools	.31	.31	.31	.31
Roads	.70	.55	.49	.77
Total cost, roadside	11.04	11.04	13.20	12.71
Value, roadside[3]	14.71	14.36	14.78	15.25
Earned stumpage	3.67	3.32	1.58	2.54
		Peeled cords		
Volume produced	27.22	44.83	66.55	116.10

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[1] Production time for the commercial clearcut plot could not be broken down because all jobs were combined in one operation.

[2] Rates: laborers at $.90 per hour; foreman at $1.27 per hour; and horse at $1.00 per day.

[3] Roadside values varied because of varying proportions of the different species.

Labor to produce a cord of wood from tree to pile ranged from 10.41 to 12.99 man-hours. The costs per cord at roadside ranged from $11.04 to $13.20. Production costs were highest for the diameter-limit method, followed by the commercial clearcutting and the two selection cuttings. We cannot explain the higher costs for the lower management intensities: we can only speculate that they are related to the higher proportions of small trees in those cuttings. In terms of earned stumpage (the difference between value and total cost of wood per cord at roadside), the plots ranked in decreasing order as follows: intensive-selection, selection, commercial clearcutting, and diameter-limit cutting (table 1). Volumes produced per acre were 2.72, 4.48, 11.61, and 6.66 cords respectively of peeled pulpwood.

After the logging job, in the fall of 1951, stand-improvement work was done in the selection and intensive-selection plots. This involved weeding, thinning, and release cutting in the intensive-selection plot, but only release cutting in the selection plot. In the intensive-selection plot 67 trees per acre were cut, including 50 that were less than 5 inches in diameter. In the selection plot only three trees per acre were removed.

A market for rough hardwood pulpwood during the winter of 1951-52 made it possible to sell about 16 cords of wood from the stand-improvement work. Total costs were $212.80, and receipts were $202.80 on the 20 acres in the 2 plots. Thus the out-of-pocket investment was 50 cents an acre.

An average of only 4.6 trees per acre on the intensive-selection plot and 3.5 trees per acre on the selection plot were considered in 1951 to warrant pruning as potential sawlog crop trees. All but one were red spruce. These trees were pruned in a special study carried out by several University of Maine silviculture students.

Second Cutting 1955 (Intensive-Selection Plot)

Felling, limbing, and peeling for the second harvest cut on the intensive-selection plot took a 4-man crew 3 days near the end of May; and 2.39 cords of wood per acre were removed. Skidding was done by a 3-man crew during 3 days in August, using a horse and small crawler tractor. Bucking and piling were done at the same time by a 3-man crew. Power saws were used for felling and bucking; axes and bark spuds were used for limbing and peeling. Labor expenditures were 11.43 man-hours per cord. Costs of production were $14.00 per cord, and roadside value $16.73 per cord, leaving a residual of $2.73 per cord as earned stumpage.

The men were paid by the hour, as in the first cutting; but both the labor rate per hour and the roadside value per cord of wood were about 12 percent higher in 1955 than in 1950.

Stand improvement on the 10 acres after this cutting consisted of killing 64 cull trees ranging from 5 to 17 inches in diameter, and 45 undesirable sound trees from 5 to 8 inches in diameter. This was done in 4 man-hours by frilling with a hatchet and treating with sodium arsenite.

Third Cutting 1959-60 (Intensive-Selection Plot)

Stumpage was sold to a local contractor for the third harvest cutting on the intensive-selection plot; 3.47 cords per acre were removed. The contractor used a crew varying from one to three men during the fall and winter. A horse was used for the skidding. Total labor expenditures were 6.89 man-hours per cord. Total costs at roadside were $9.97 per cord; the value was $14.16, leaving an earned stumpage of $4.19 per cord. Sixteen cull trees marked for removal were cut by the operator. No other stand-improvement work was necessary.

A significant point noted here is that production costs under contract cutting were appreciably lower than in the previous cuttings when labor was paid by the hour.

Results

IMMEDIATE STAND CHANGES

The immediate results of cutting on a stand can be expressed in two ways: (1) by the reductions in volume per acre, and (2) by changes in proportions of the different species or species groups.

The reductions in volume after the first cut, in terms of both cubic feet and rough cords[4] per acre, are shown in the following tabulation:

Cutting method	*Before cutting, 1950*		*After cutting, 1951*	
	(cu. ft.)	*(cords)*	*(cu. ft.)*	*(cords)*
Commercial clearcutting	2,092	24.61	761	8.95
Diameter-limit	1,970	23.18	1,291	15.18
Selection	1,779	20.93	1,378	16.21
Intensive selection	2,055	24.18	1,759	20.70

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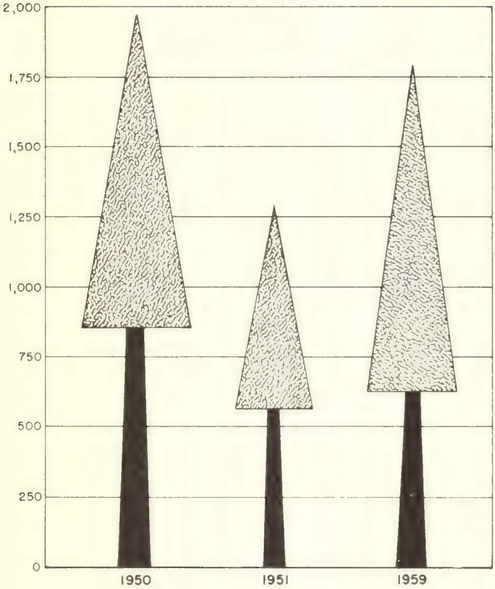
[4] A rough cord contains 85 cubic feet of wood.

Figure 2.—Commercial clearcut plot: cubic-foot volume per acre, by years.



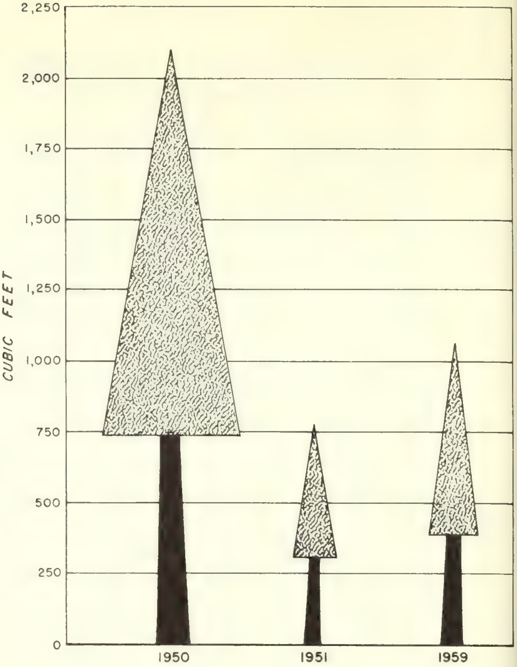


Figure 3.—Diameter-limit plot: cubic-foot volume per acre, by years.

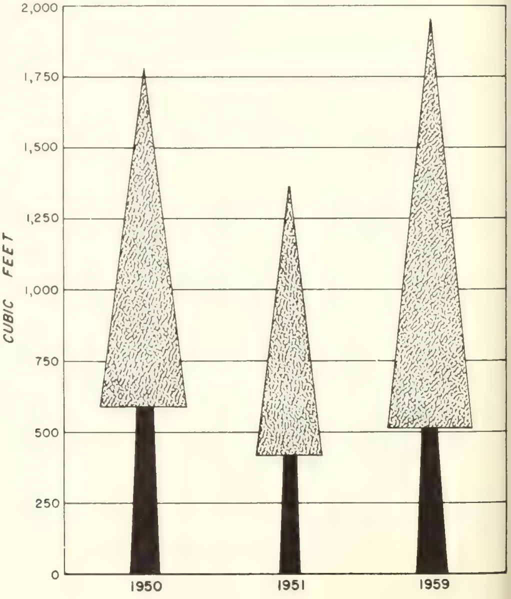


Figure 4.—Selection plot: cubic-foot volume per acre, by years.

Figures 2 to 5 depict these cubic-foot changes graphically, and also the volumes as of 1959. Changes in proportions of species and species groups on a cubic-foot volume basis are shown in figure 6. This figure also presents the situations in 1959, as well as those before and after cutting in 1950 and 1951.

Many of the changes in 1951 were comparatively small, except in the clearcutting. On that plot, spruce and fir together were reduced from 72 percent to 34 percent, and the proportions of other species increased accordingly. Other softwoods (cedar, pine, and larch) went from 12 percent to 32 percent, and hardwoods from 12 percent to 28 percent.

Of particular interest in both selection cuttings were the modest increases in the proportion of spruce and the associated decreases in the hardwood component. These changes reflected progress toward improving species composition — one of the basic goals in selection management.

For the intensive-selection plot — the only one cut since the initial treatment — the ups and downs in volume that are associated with the second and third cuttings in 1955 and 1960 are depicted in figure 5. The volume after the 1960 cut was 1,822 cubic feet per acre, as compared to 1,759 cubic feet in 1951. As of 1959, the proportion of spruce had risen from an original 26 percent to 35 percent, and hardwoods had dropped from an original 18 percent to 10 percent (fig. 6).

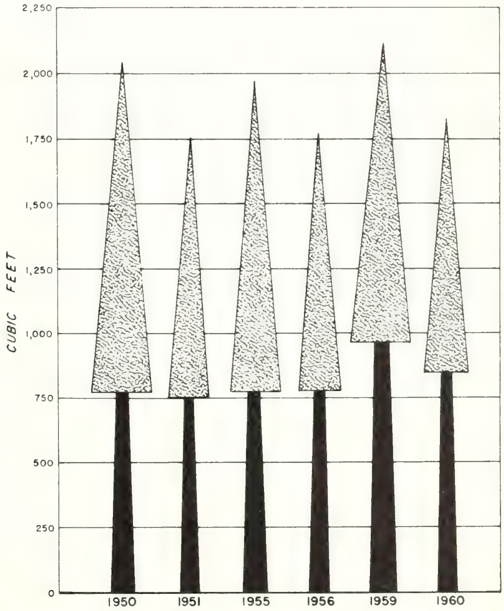


Figure 5.—Intensive-selection plot: cubic-foot volume per acre, by years.

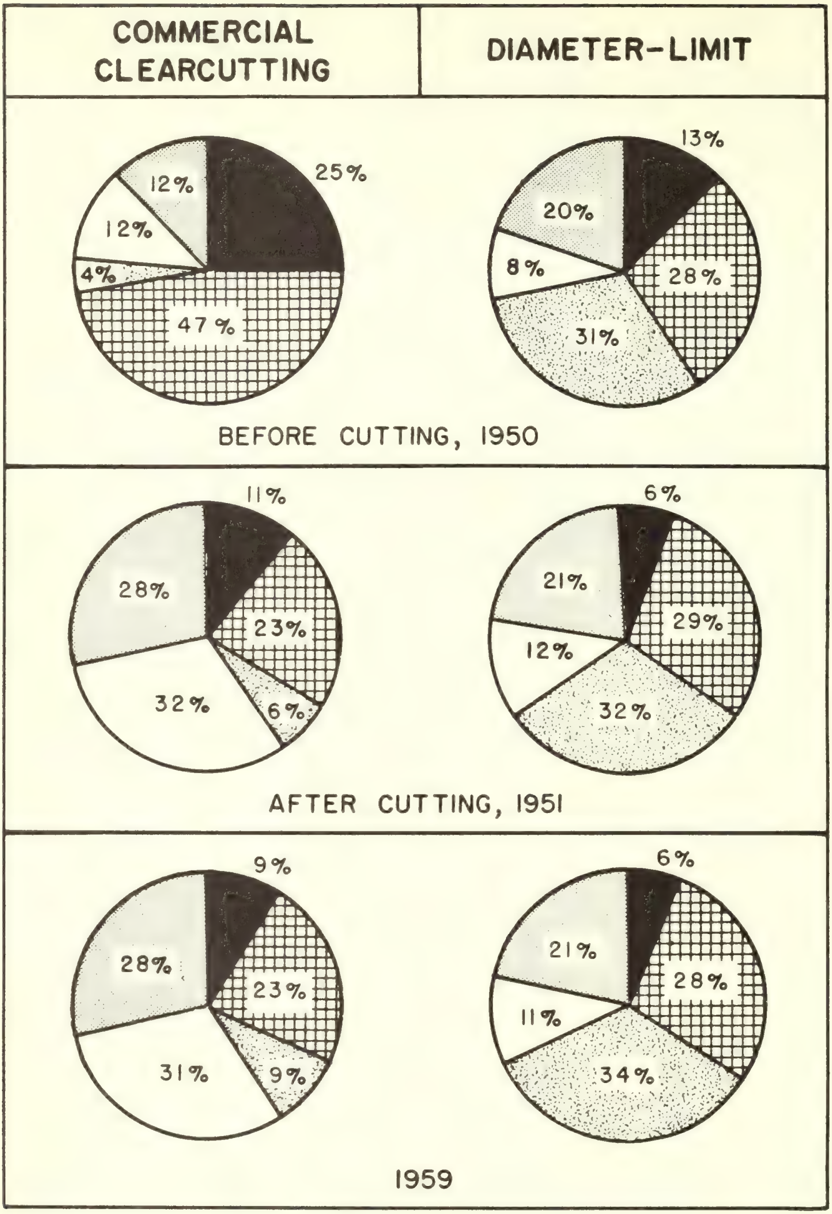
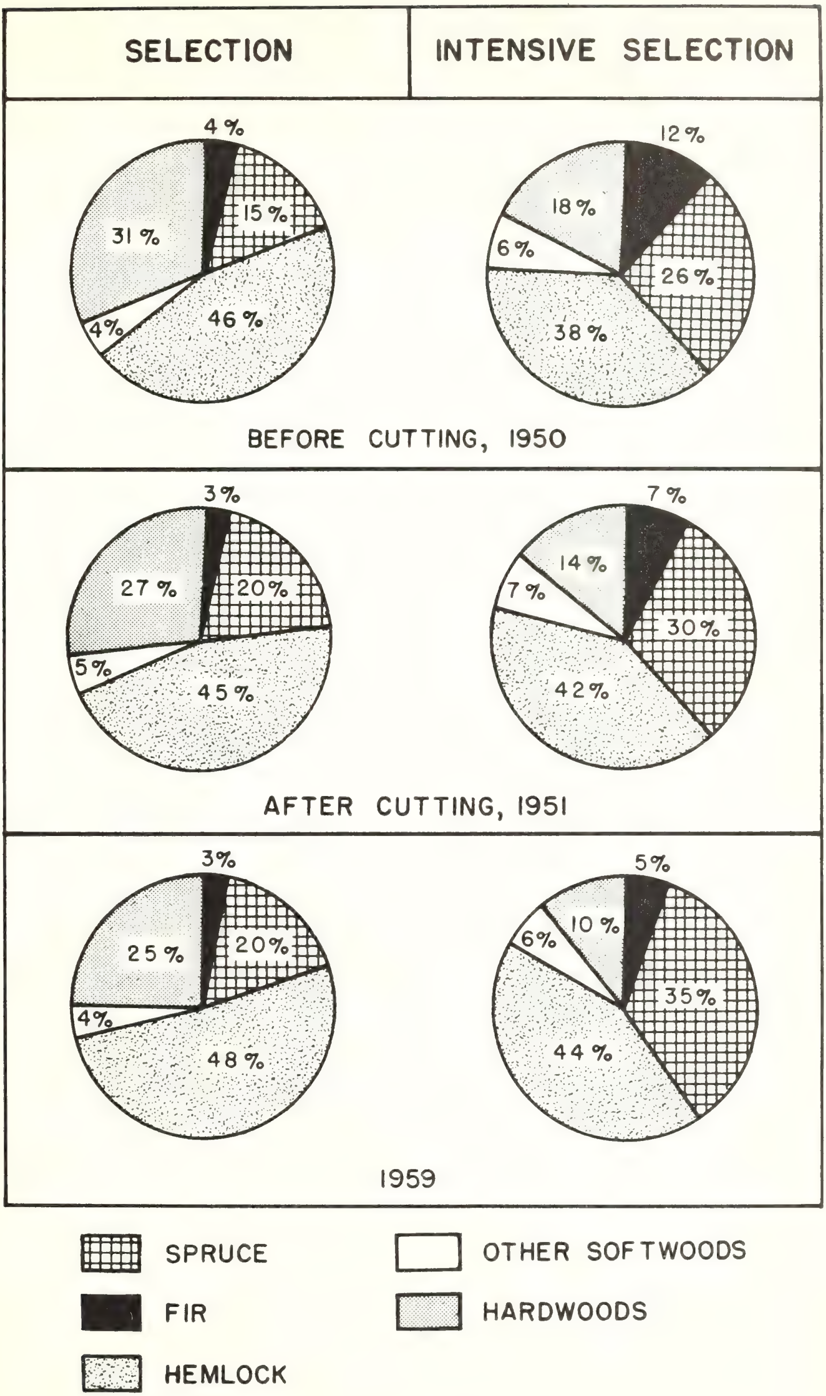


Figure 6.—Species composition, expressed in volume percentages by management intensity, before and after the first cuttings and 9 years later. In the intensive-selection plot a second cutting was made in 1955 and the diagram for 1959 depicts the situation just before the third cutting.


SELECTION
INTENSIVE SELECTION
4 %
15 %
31 %
4%
46 %
12 %
18 %
6 %
26 %
38 %
BEFORE CUTTING, 1950
3%
20%
27 %
5%
45 %
7 %
14 %
7 %
30 %
42 %
AFTER CUTTING, 1951
3%
20%
25 %
4%
48 %
5%
10 %
6%
35 %
44 %
1959
SPRUCE
FIR
HEMLOCK
OTHER SOFTWOODS
HARDWOODS

RESPONSE TO TREATMENTS

Mean annual gross growth per acre from 1951 through 1959 ranged from 56 cubic feet on the clearcut plot to 86 cubic feet on the selection plot; net growth ranged from 40 cubic feet for the clearcutting to 71 cubic feet for the intensive-selection cutting (table 2). Although considerably more growing stock was retained in 1951 on the intensive-selection plot than on the selection plot, gross growth and net growth were each almost identical on the two plots. Thus the net growth rate for the intensive-selection plot, when expressed in percent of the 1951 growing stock, was appreciably lower — 4.0 percent versus 5.1 percent. In figure 7, mean annual gross growth is broken down graphically into its basic components — net accretion, ingrowth, and mortality.

Ingrowth for the 9-year period accounted for 27 percent of the gross growth on the clearcut plot, 20 percent on both the diameter-limit and selection plots, and 17 percent on the intensive-selection plot. Mean annual ingrowth as a percent of 1951 cubic-foot volume is shown graphically in figure 8, by species groups. For all

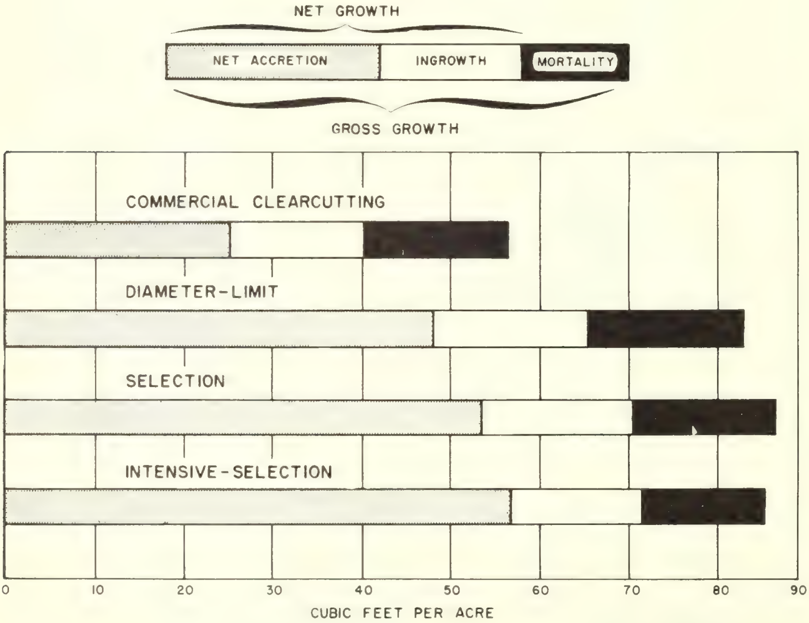


Figure 7. — Mean annual volume growth per acre, by management intensity and growth components — 1951-1959.

Table 2. — Mean annual growth and mortality, 1951-59, by management intensities

Treatment	Residual stand, 1951	Gross increment	Mortality	Net increment	Net growth rate
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Percent*
Commercial clearcutting	761	56	16	40	5.3
Diameter-limit	1,291	83	18	65	5.0
Selection	1,378	86	16	70	5.1
Intensive-selection	1,759	85	14	71	4.0

Table 3. — Percentage of milacres stocked with seedlings in 1951 and 1959, by management intensities and species

Species	Commercial clearcut		Diameter-limit		Selection		Intensive-selection	
	1951	1959	1951	1959	1951	1959	1951	1959
Fir	57	78	32	78	45	62	58	68
Spruce	12	38	5	30	38	32	2	10
Hemlock	2	22	22	68	20	52	18	42
Pine	2	15	12	12	2	5	2	8
Cedar	0	20	2	2	0	0	0	8
Larch	0	2	0	0	0	0	0	0
Maple	5	10	5	10	8	22	15	12
White birch	32	28	30	40	2	10	15	8
Beech	0	0	0	2	15	15	5	10
Other hardwoods	0	35	0	8	0	0	0	2
Not stocked	22	10	37	10	12	8	28	20

Table 4. — Numbers of trees 4.5 feet tall to 0.5 inches d.b.h. per acre in 1959

Species	Commercial clearcut	Diameter-limit	Selection	Intensive-selection
Fir	145	25	110	75
Spruce	5	0	40	5
Hemlock	0	5	30	5
Pine	0	0	0	0
Cedar	0	0	5	0
Larch	5	0	0	0
Maple	130	95	5	5
White birch	0	0	0	0
Beech	0	5	5	0
Other hardwoods	50	5	0	0

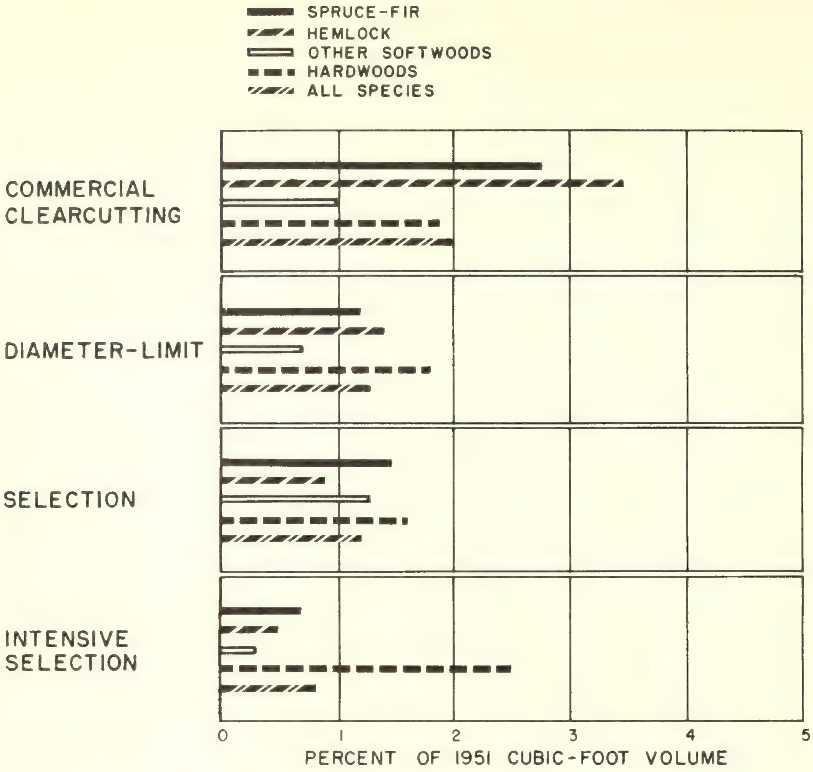


Figure 8.—Mean annual ingrowth per acre, as percent of 1951 volume, by management intensity and species group.

species collectively, annual ingrowth ranged from 2 percent of the 1951 volume on the clearcut plot down to 0.8 percent on the intensive-selection plot.

Mean annual mortality, as a percent of 1951 cubic-foot volume, is shown graphically in figure 9, by species groups. For all species, the losses ranged from 2.1 to 0.8 percent. It is curious that annual ingrowth and annual mortality for all species are almost identical (figs. 8 and 9) ; and it is equally curious that these two growth components, as expressed in cubic feet (fig. 7), are nearly equal within management intensities. This may be largely coincidence; when individual species groups are compared (figs. 8 and 9), many dissimilarities are evident.

Cutting stimulated the establishment of reproduction (stems less than 4.5 feet tall) on all plots. The percentages of milacres

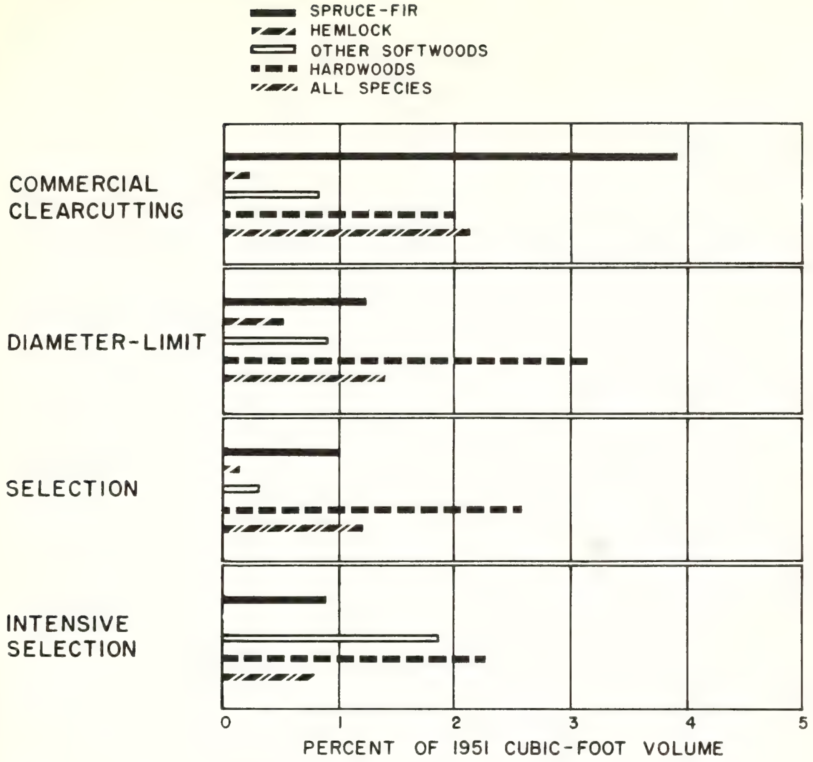


Figure 9. — Mean annual mortality per acre, as percent of 1951 volume, by management intensity and species group.

that were not stocked with established seedlings declined under each treatment between 1951 and 1959 (table 3). A seedling was considered established if it had developed one or more branches.

Fir was the most numerous species in the reproduction in 1951, and still was most numerous in 1959. Hemlock was second in 1959 on all but the commercial clearcut plot, where spruce was second. Other hardwoods — including gray birch and the aspens — were a close third.

In terms of the numbers of stems per acre in trees 4.5 feet tall to 0.5 inch d.b.h. (table 4), balsam fir was first, followed by spruce and hemlock, on the two selection plots. Fir also predominated on the clearcut plot, with red maple a close second; but it was exceeded by red maple on the diameter-limit plot.

Discussion

In cutting systems based upon individual tree selection, a forest manager can manipulate growing-stock levels and stand structure in an effort to achieve his management objectives. These objectives commonly are maximum growth and quality production for a given intensity of management. However, little research information is available for determining the best stocking and stand-structure goals to work toward in any specific forest situation. Selection of these goals is in large part a matter of judgment.

Stocking and stand-structure goals have been set up for the two selection plots in the Penobscot study as part of the overall study planning, and the cuttings on those plots have been pointed toward eventual attainment of those goals, which are described, together with some graphic information on progress toward their attainment, in an appendix (page 21).

But these silvicultural goals are secondary here. The pertinent question is: have the Penobscot demonstration plots accomplished the objectives set for them? In 9 years, the first two objectives for the cutting-practice plots have been accomplished very well. More time will be needed before the third objective can be accomplished fully.

The first objective was to provide examples of different cutting practices as an aid to forest owners and managers. More than a thousand people have examined the four plots since they were established in 1950. Among these visitors have been not only forest owners, farmers, industrial woodland managers, company officials, professional foresters, and forestry students, but also bankers, Grangers, and other interested laymen.

In the second objective — to provide experience and training to the spruce-fir management staff — the demonstration plots have been an excellent training ground for our local researchers. The plots have served as a springboard for the plunge into a compartment management study in which all the treatments used in the demonstration, plus several additional ones, are being tested and compared on a larger scale.

The third objective — to get preliminary cost and return data — has been realized only to a limited degree. Long-term comparisons of costs and returns among the four intensities of management will not be possible until the commercial clearcut plot again reaches an operable stage. Even among the other intensities, more cuttings must be made before definite data on returns will be available. However, the following generalizations do emerge rather clearly from our 9-year records and experience:

- In stands similar to those on the plots, light partial cuttings are possible with no greater expenditure per unit of volume for labor and equipment than in commercial clearcutting.
- Net growth per acre after cutting is more than twice as much where a reasonable amount of growing stock is retained than where clearcutting has reduced growing stock to a minimum.
- As long as a stand is reasonably well stocked, variations in the amount of stocking make little difference in the quantity of wood grown annually per acre.

Certain advantages and certain disadvantages are associated with each of the cutting methods represented on the demonstration area. Selection cutting favors: stand improvement, accelerated increment of merchantable volume, reduced fire hazard as compared to clearcutting, continued protection of the soil, prevention of weed-plant growth, and probably more efficient wood production. Selection cutting also permits close control of the growing stock and more salvage of the natural mortality. Usually the end products for harvesting are of higher quality than in other cutting methods. Moreover, the frequent cuts provide a continuous supply of game food.

The main disadvantages, as compared with other cutting methods, are that in selection cutting, management is more complicated, tree marking is required, the cost per unit volume for temporary logging facilities such as camps and bulldozed truck roads is increased, and the dense stocking may eventually eliminate — unless interrupted by a catastrophe — the less shade-tolerant species such as pine and birch.

Clearcutting has the advantage of not requiring marking; and because of the larger volume of wood removed, clearcutting entails the lowest cost for temporary logging improvements per unit of volume. However, clearcutting has definite disadvantages: it leaves the land with limited means for natural regeneration of desirable species, unless advance reproduction is present; it removes minimum-sized merchantable trees during their period of rapid growth; 16 to 20 percent of the area is cleared for roads; dense slash smothers reproduction and prevents establishment of new seedlings for 15 years or more; fire hazard is increased for at least 10 years after cutting because of the dense slash, and for an additional 15 or 20 years because of even-aged reproduction; a long period of time elapses before another cut can be made; usually the quality of harvested products is lower; and game food, although initially produced in abundance, soon grows out of reach of the animals.

Clearcutting would be a logical method to apply in mature or overmature stands where a good crop of advance reproduction is present, and where partial cutting would result in considerable mortality of reserved trees. Stands in remote areas and on poor sites also might be cut in this manner.

Diameter-limit cutting is a compromise between selection cutting and clearcutting. It is best applied in vigorous young stands having a nearly uniform distribution of size classes. Minimum-sized merchantable trees in stages of rapid growth are retained for another harvest in the forseeable future. Usually, however, a diameter-limit cutting results in uneven stocking. And it tends to remove many vigorous trees above the limit while leaving defective and poor-vigor trees below the limit.

Under present economic conditions, intensive-selection cutting can be applied profitably only to the most accessible stands on the best sites. Many owners of small woodlots are in this enviable position and should be able to profit by adopting such management.

For the vast areas of second-growth forest, owners and managers should carefully weigh the advantages and disadvantages of each cutting method in the light of their particular situations and needs. In general, partial cutting — either to carefully picked diameter limits or by marked tree selection — is probably the most effective practical way to perpetuate these second-growth spruce-fir stands.

Summary

Four different methods of cutting merchantable spruce-fir-hemlock stands—commercial clearcutting, diameter-limit cutting, selection cutting, and intensive selection cutting — were applied on 10-acre demonstration plots on the Penobscot Experimental Forest in central Maine. Besides providing effective demonstrations of the four cutting practices, the plots have shown in their first 9 years that —

- Production costs per cord at roadside were highest for the diameter-limit method, next the clearcutting, then the two selection methods.

- Net growth per acre per year — 65 to 71 cubic feet (0.77 to 0.84 cord) — was very nearly the same for the diameter-limit, selection, and intensive-selection plots. On the clearcut plot the net growth was much less—40 cubic feet (0.47 cord) per acre.
- Mortality was greatest on the clearcut plot, and diminished with increased stocking of the reserved stand. Fir, beech, and yellow birch had the highest mortality rates.
- The commercial clearcutting reduced the proportion of spruce-fir and increased the proportion of other softwoods and hardwoods. Diameter-limit cutting reduced the proportion of fir, but had little effect on other species. Selection cutting slightly increased the proportion of spruce-fir and decreased hemlock slightly. Intensive selection reduced the proportion of fir and hardwoods but increased spruce and hemlock.
- All the cuttings stimulated the establishment of new reproduction. Balsam fir led all other species in new seedlings.

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Appendix

STAND STRUCTURE GOALS FOR SELECTION PLOTS

No one knows the optimum growing stock level that should be maintained in spruce-fir stands to produce the greatest growth values. Until such information is available, we have to make certain assumptions and set up tentative stocking and stand structure goals.

If no major catastrophes such as fire, disease, or insect attack occur, a balanced, uneven-aged structure should provide an uninterrupted periodic yield on the two plots managed on the selection principle. The fundamental characteristic of such a balanced, uneven-aged stand is a gradual decrease in numbers of trees by diameter classes as the diameters increase, with the same ratio prevailing between numbers of trees in successive diameter classes. When plotted on semilogarithmic paper, the numbers of trees by diameter classes should approximate a straight line.

The goal in both selection plots is to build stand structures that can be maintained by the selection system of management, operating in one plot on a 5-year cutting cycle and in the other plot on a 15-year cycle. Under the 5-year cycle on the intensive-selection plot, most of the poorer trees have been removed after three cuts. Future cuts at 5-year intervals will

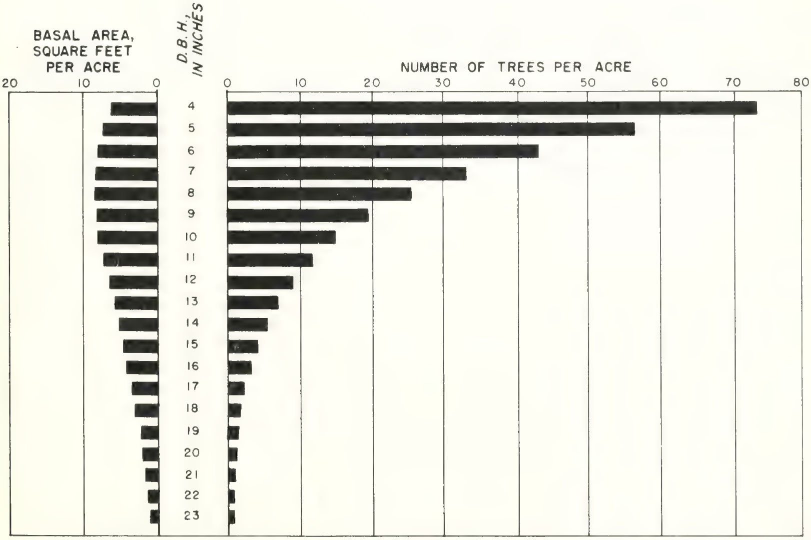

Figure 10. — Stand and stocking goals after each cutting under intensive-selection management.

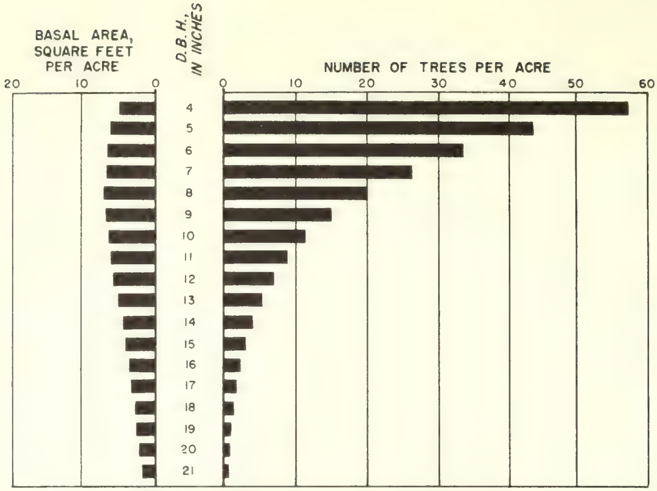

Figure 11. — Stand and stocking goals after each cutting under selection management.

gradually mold the stand toward a balanced, uneven-aged form. Under the 15-year cycle on the selection plot, the second cut — to be made in 1965 — will begin to convert that stand to the desired form. Eventually this should result in stands where each cut can equal the periodic growth while maintaining the basic structure of the growing stock indefinitely.

The trees on these two plots are of all sizes, and their diameter-class frequencies now resemble those of the typical all-aged structure. The resemblance will become closer with each succeeding cut until the stand-structure goals are attained.

The goals chosen for the intensive-selection plot at the beginning of a cutting cycle are: 120 square feet of basal area, 23 inches d.b.h. as the maximum tree size, 0.5 tree of this size per acre, and "q" (the ratio between tree numbers in successive diameter classes) of 1.3.

For the selection plot, the goals are: 90 square feet of basal area, 21 inches d.b.h. maximum tree size, 0.7 tree of this size per acre, and the same "q" — 1.3. On both plots, a maximum tree size of 24 inches d.b.h. is anticipated at the end of the cutting cycles.

These stand-structure goals are based on available silvicultural information and prevailing market demands and utilization practices. Integrated products are the present management objective. The goals, particularly with respect to maximum tree sizes, definitely should be viewed as flexible and subject to change as future circumstances may warrant.

With the present management objectives in mind, the stand and stocking goals — in terms of numbers of trees and square feet of basal area by diameter classes — were worked out for each of the two intensities of selection management (figs. 10 and 11). Also, for each management intensity, the theoretical distribution of basal area among diameter classes shown in figures 10 and 11 for the stocking goals is compared to actual distributions at different times during treatment of the stands on the two plots (figs. 12 and 13). And finally, actual and theoretical distributions of basal area by 4-inch d.b.h. size classes are summarized in table 5.

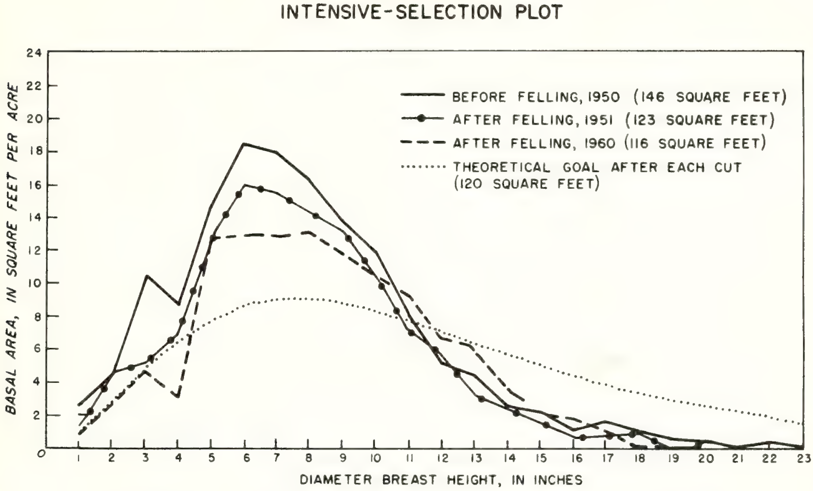

Figure 12. — Basal-area distribution per acre, all species, by 1-inch diameter classes. Intensive-selection plot.

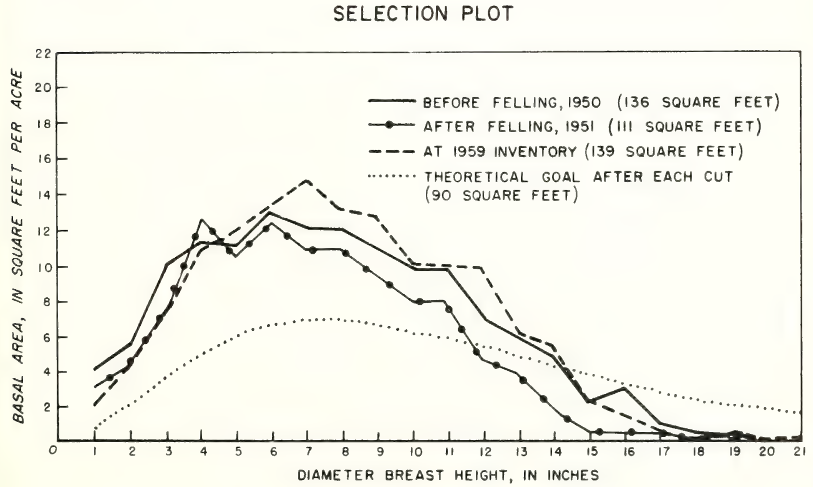

Figure 13. — Basal-area distribution per acre, all species, by 1-inch diameter classes. Selection plot.

Table 5. — Distribution of basal area, by d.b.h. size classes

Year	Total basal area	Sub-merchantable: 1-4 inches	Small: 5-9 inches	Medium: 10-14 inches	Large: over 14 inches
	Square feet	*Percent*	*Percent*	*Percent*	*Percent*
		SELECTION PLOT			
1950	136	23	44	27	6
1951[1]	111	25	49	24	2
1955	117	20	50	27	3
1959	137	18	48	30	4
Theoretical goal	90	13	37	30	20
		INTENSIVE-SELECTION PLOT			
1950	146	18	55	22	5
1951[1]	123	15	58	24	3
1955[1]	126	17	54	26	3
1959[1]	116	10	54	31	5
Theoretical goal	120	12	36	29	23

[1] After cutting.

It is obvious that the goal on the intensive selection plot will not be reached for perhaps 30 years or more because the stand contains so few trees larger than 18 inches d.b.h. The goal may be reached sooner on the selection plot, because some trees of all sizes up to and including 21 inches d.b.h. are now present. Cuts in the immediate future in both plots should be concentrated on the small and medium-sized trees. Trees larger than 14 inches d.b.h., unless in poor condition, should be retained through the next few cutting cycles so as to build up growing stock in the larger diameters.

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Root Systems

of direct-seeded and variously planted loblolly, shortleaf, and pitch pines

by s. little
and h. a. somes

Root Systems

of direct-seeded and variously planted loblolly, shortleaf, and pitch pines

the authors . . .

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The Root Problem

THOUGH tree planting has long been a major forestry practice in the Northeast, it has resulted in relatively few wholly successful stands. Survival has often been low. Where survival has been high, the trees in some plantations have been slow-growing or misshapen. Even when planted trees do grow well for a while, they commonly are short-lived: scattered trees die from no apparent cause, or a swath of trees may go down in a wind storm. Attrition of this sort tends to continue until the stand is largely destroyed or is removed in a salvage cutting. Only in occasional instances or in certain places do plantations give promise of growing as well as the best natural stands.

Poor performance of plantations may be due to one or more of several causes: low-quality stock, wrong species, wrong seed source, unsuitable site, and nursery and planting practices that are geared more to cost than to quality considerations. Though most states now are taking steps to provide good stock of suitable species and source, and to match species and site, relatively little attention has been paid to practices that may greatly influence disease susceptibility, and hence plantation longevity and growth.

Pathologists pointed out long ago that planted trees were more susceptible than natural stands, especially to root rots (Boyce 1938, Baxter 1943). Other authors have shown that, on two-thirds of the planted trees in some areas, the root systems may be severely deformed in planting (Gruschow 1959); that these root deformities may cause increased mortality (Rudolf 1939, Brown and Carvell 1961, Ursic 1963); and that they may reduce height growth by as much as 20 percent (Rudolf 1939).

In the Northeast, most evidence of the effects of planting practices on seedling survival, tree form, growth, and disease infection has been observational. To obtain more reliable information on those effects, the Northeastern Forest Experiment Station in 1960 started a long-term experimental study with three pine species in southern New Jersey. The study was designed to compare direct seeding with several planting procedures in terms of tree performance through the period of a stand rotation. As part of the study, sample seedlings were excavated in 1962 to determine the early effects of the treatments on root systems. This paper describes and pictures the root systems, and the differences among them that relate to the method of seedling establishment.

Study Methods

The three species used were loblolly, shortleaf, and pitch pines. Each was direct-seeded and planted as 1-0 and 2-0 stock, and the planting was done in three ways: center hole, good slit, and poor slit. Thus there were 21 species-treatment combinations.

Center-hole planting called for digging holes, usually with a spade, and spreading the roots out in a position similar to their position in the nursery. In slit planting, planting bars were used. Good slits were made deep enough to accommodate the length of the taproots, and planters were instructed to maneuver the roots so that they hung vertically. Poor slits were deliberately made shallow enough (to simulate careless planting) so that roots were bent in an L or J shape. Direct seeding was done by spading spots, dropping 12 sound seeds per spot, lightly covering them with soil, and protecting each spot with a hardware cloth cone.

The same seed lot provided seedlings for all treatments within a species. The pitch pine seeds were collected in the Lebanon State Forest and the shortleaf pine seeds in the Wharton State Forest in 1959. Loblolly pine seeds from the 1958 crop on the Eastern Shore were provided by the Maryland Department of Forests and Parks. The New Jersey Department of Conservation and Economic Development extracted the pitch and shortleaf pine seed, and grew all the required seedlings at their Washington Crossing Nursery. These seedlings were started in 1960.

Two sites were selected for field tests — one in the Wharton State Forest and one in the Lebanon State Forest. Both sites had been occupied by oak-pine stands, but the Lebanon area had recently been cut over, and the Wharton area had been subjected to a killing wildfire. (Regrowth in both areas has since been controlled by cutting and silvicides.) The soils of both areas are sandy. Those at the Lebanon site are gradational between the Lakeland and Lakewood series, which differ primarily in depth of the leached A_2 horizon. The soils of the Wharton site are somewhat heavier and less leached, and are considered to be of the Sassafras series.

At each site two 0.1-acre plots were laid out for each of the 21 treatment combinations. Each plot provided for 121 seed spots or planted seedlings at 6-foot spacing. Only the inner 49 trees were to be measured; the outer two rows all around were regarded as isolation strips.

All plots that were to be direct-seeded were seeded in March 1961, and plots that were assigned 1-0 seedlings were planted that spring. Plots assigned 2-0 stock were planted the next spring — 1962. Sufficient stock was available both years to permit culling out most of the smaller and damaged seedlings.

In November 1962, one seedling that appeared typical of those in each plot was excavated from the isolation strip. Dry excavation methods were employed: a fairly deep hole was dug on one side of the seedling, with shallower ones on the other sides, and screwdrivers were used to loosen the roots and pull the sandy soil into the holes. Care was taken to remove the root system as intact as possible. In all, 84 seedlings — 1 per plot or 4 per treatment combination — were excavated.

Results

Seeded Seedlings

All direct-seeded seedlings had relatively normal root systems. Taproots usually had penetrated nearly vertically into the soil. Laterals had developed on all sides and had grown away from the taproots almost at right angles (fig. 1).

There was one striking exception, a shortleaf pine seedling in which the tip of the taproot had died and a lateral had taken over (fig. 2). Surprisingly, this root had penetrated to a depth of 37.5 inches — a greater depth than had been reached by the taproot of any other direct-seeded seedling that was excavated. By develop-

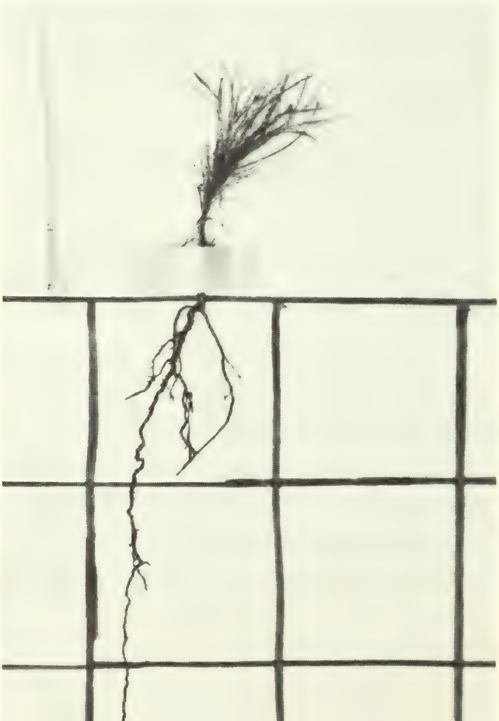


Figure 1.—Typical seeded seedling of pitch pine excavated at the end of two growing seasons. (3-inch grid.)

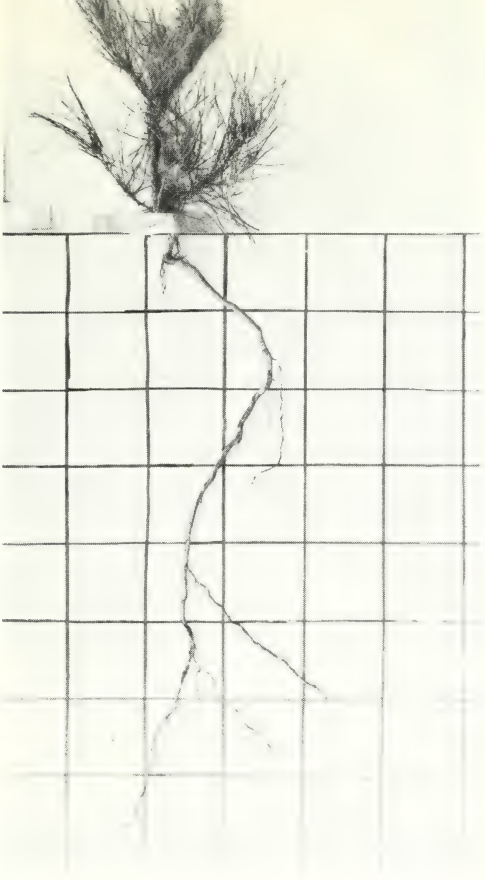


Figure 2.—A direct-seeded 2-year-old shortleaf pine seedling on which the taproot soon died, possibly because of insect injury, and was then replaced by a lateral root. (3-inch grid.)

ment of lopsided growth rings, this seedling could easily mask the crook in its main root by the time root diameter at that point has reached 6 inches.

Planted Seedlings

The roots of planted seedlings differed from those of seeded seedlings in several ways. One of the most notable differences was the occurrence in the planted trees of twisted, intertwined roots in the upper 3 inches or so of the root systems. This condition was not found in the direct-seeded trees.

Such intertwined roots characterized 94 percent of the excavated planted seedlings. They were most conspicuous on seedlings planted in poor slits as 1-0 stock (fig. 3), but some occurred also on similar seedlings planted in center holes or good slits. On 2-0

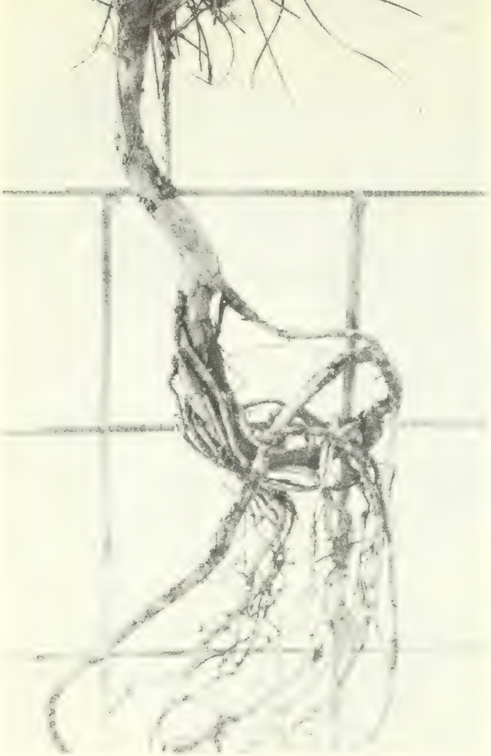


Figure 3. — Intertwined roots of a shortleaf pine seedling two growing seasons after planting as 1-0 stock in a poor slit. (3-inch grid.)

stock intertwined roots, although usually present, were not so conspicuous — probably because these trees had had 1 year less for growth since planting.

Nearly all the seedlings planted in slits had root systems that were developing only in one plane. This was particularly true of those in poor slits. However, even in good slits, only two excavated seedlings — one pitch pine and one shortleaf pine — were developing relatively normal root systems. Both of these seedlings had been planted as 1-0 stock and were still small.

Planting in slits tended to produce J- or L-shaped taproots. Although deformities of this kind were deliberately induced in the poor-slit method, 25 percent of the seedlings excavated from good-slit plantings also had J- or L-shaped taproots. In these cases, the planters evidently had not taken sufficient care to have the taproots hanging free in the holes before closing them. Of course, where good-slit planting was properly done, root systems were more nearly normal in appearance (fig. 4).

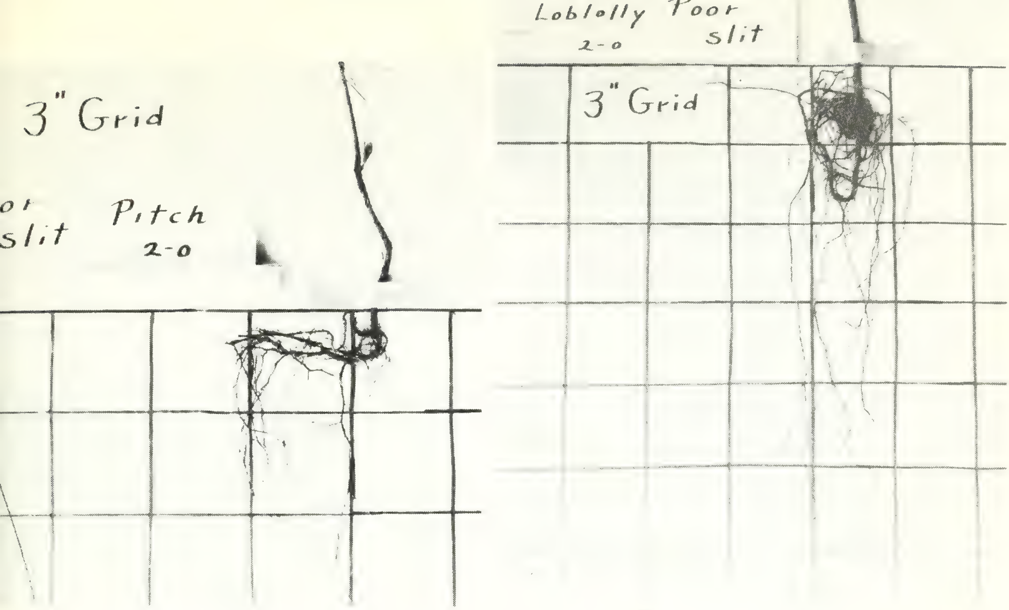
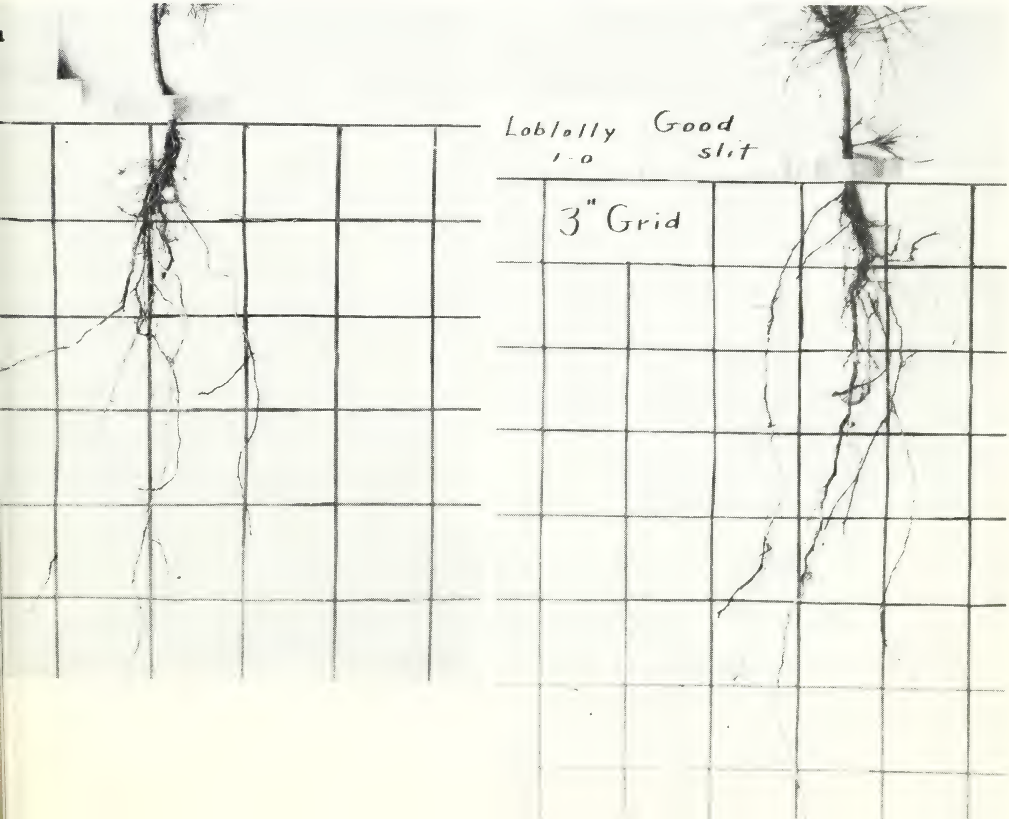


Figure 4. — Contrast in the root systems resulting from poor-slit and good-slit planting. Above: pitch and loblolly pine seedlings planted as 2-0 stock in poor slits. Below: the same species planted as 1-0 seedlings in good slits.



The 1-0 seedlings showed greater flexibility in recovering from poor planting than did the 2-0 stock. Ursic (1963) has already observed and described the recovery of root systems in 1-0 loblolly pines from U-root planting. In our study the roots of all the excavated 1-0 seedlings that had been planted in poor slits had reacted either by the taproot itself growing in an abrupt turn downward from the end of the J or L (fig. 5) or, in some cases,

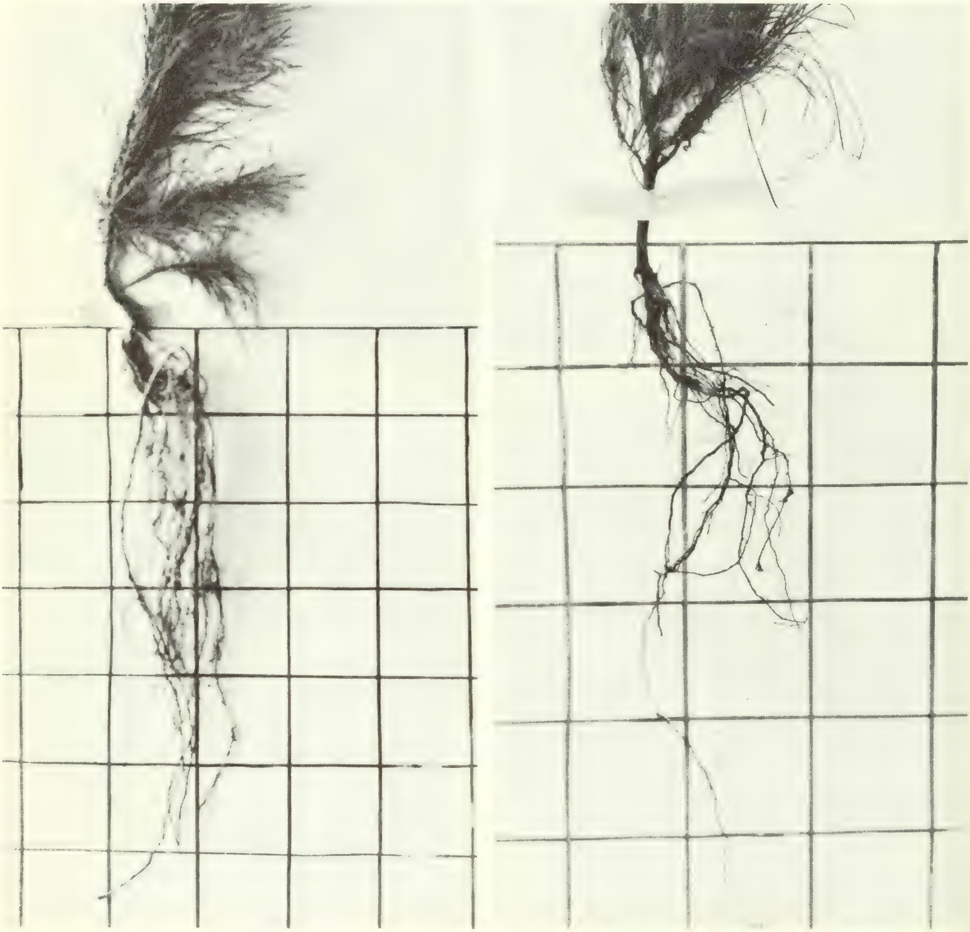


Figure 5.—Recovery of taproots in two growing seasons after 1-0 seedlings were planted in poor slits with taproots in an L or J position. Note the U-turn in the taproot of the shortleaf pine seedling (left) and the L-turn in that of the loblolly pine (right).

by another root replacing it. When the latter happened, most of the development of the replacement root seemed to have occurred since planting. In part because of less elapsed time, the 2-0 seedlings planted in poor slits had made less recovery. In some, as in one shortleaf pine planted with most of its root system above the base of the stem, a new taproot had scarcely started.

Center-hole planting resulted in more spreading root systems than slit planting (fig. 6 compared to figs. 4 and 5). Theoretically, planting in center holes should result in nearly normal root systems with laterals spreading in all directions and taproots growing downward without marked deformities.

However, the desired objective was not achieved. In nearly half of the excavated seedlings from center-hole planting most of the roots were in one plane, and in many others one side had few or no roots. Frequently, too, the taproots were deformed: either they had a J or L shape or they had been spread out like lateral roots in the planting. Though the amount of distortion of taproots was not so great as in poor-slit planting, and though root systems were more spreading than in either type of slit planting, root distribution in the center-hole planting still was far from normal. In view of the difficulty in distributing the flexible, bare roots in their natural positions, this is understandable.

To achieve proper placement of roots in center-hole planting, the root system should not be pressed against one side of the hole: the taproot should hang vertically, and lateral roots should be spread out on all sides. This is slow, tedious work. Planters, by and large, will not take the requisite time and care in separating and placing the roots in the hole.

Surprisingly, the three methods of planting caused little difference in the depth of taproot penetration in 1962, although differences did occur between ages of stock and between planted and direct-seeded seedlings. As might be expected, the greatest depth of taproot penetration was by seedlings planted as 1-0 stock, the average values being 21 or 22 inches for the slit treatments and 24 inches for the center-hole method. Average values for seedlings planted as 2-0 stock by comparable methods were 4 to 11 inches less than for the 1-0 seedlings, mainly because these seedlings had

had one less growing season in the field since planting. The average taproot penetration by seeded seedlings approached that of 2-0 stock, but these were 1 year younger from seed than either the 1-0 or 2-0 planted seedlings.

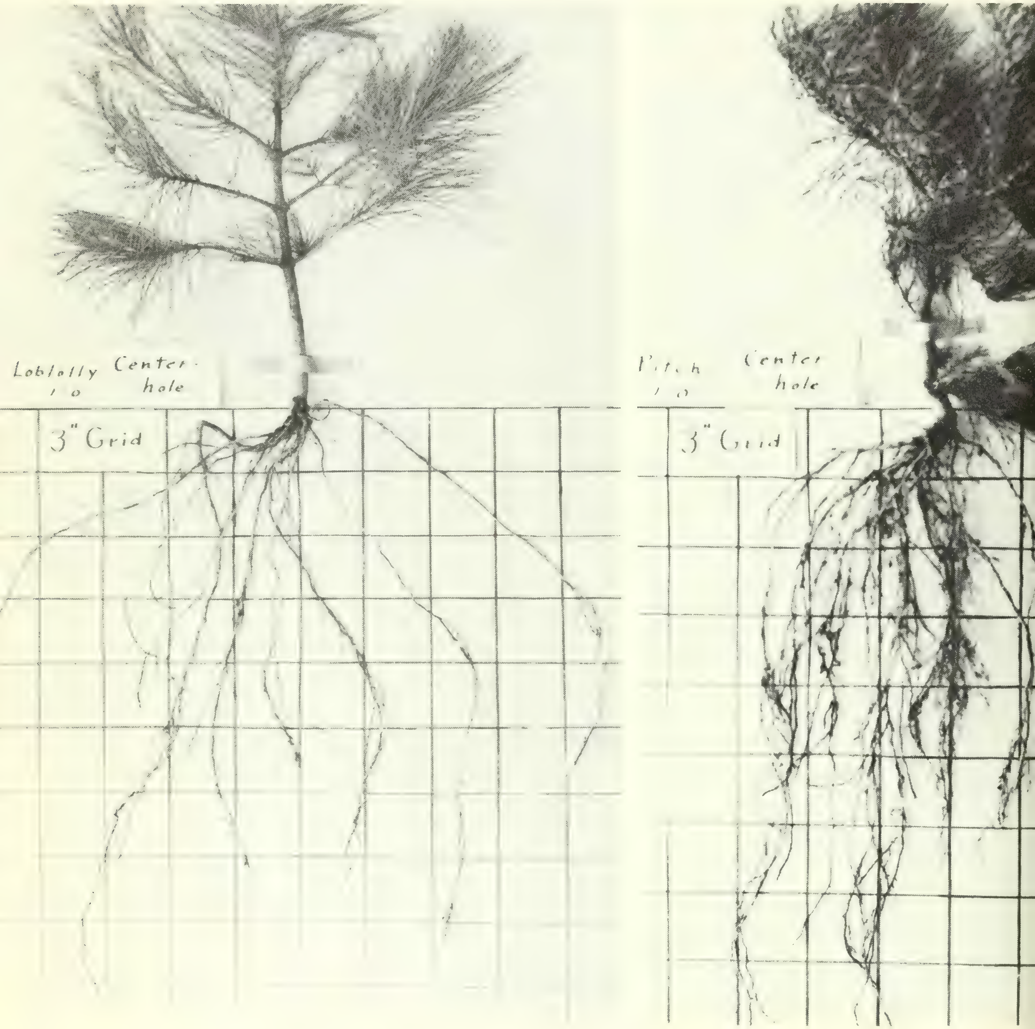


Figure 6.—Seedlings planted in center holes as 1-0 stock, photographed two growing seasons later. Note that the root systems are more spreading than those of slit-planted seedlings, but that, as shown in the loblolly pine seedling, root systems did not escape distortion.

Discussion

Although the seeded seedlings of this study were younger and smaller, their root systems were in marked contrast to those of the planted seedlings. The seeded seedlings did not exhibit the one-plane pattern of root distribution found in the root systems of planted trees, and they did not have distorted taproots and intertwined laterals.

Intertwined roots near the surface, common on most of the planted seedlings, warrant emphasis because they are a possible source of disease infections. Even though Station pathologists found indications of infection on only one of the excavated root systems, the intertwined roots, as they grow, will strangle each other and provide dead material for invasion by wood-decaying fungi. Gruschow (1959) observed rotten roots on several loblolly pines 3 years after planting with J-shape or balled root systems. Ursic (1963) found twisted roots on planted loblolly pines and considered the twisting as potentially more serious than U-root planting.

The extent to which the planted seedlings can overcome distortions in their root systems remains to be seen. Bilan (1960) investigated slit-planted 1-0 loblolly pines in Texas and reported that during the first growing season most of the growth in lateral roots continued to be in the plane of the slit. Stevens (1931) reported a similar bunching of roots in one plane on white pines 3 years after planting. Certainly in our study, the more severely distorted root systems of stock planted in poor slits offer much less promise of ultimate recovery than do those planted by the other two methods.

The greater recovery in root systems of 1-0 seedlings than of 2-0 seedlings seems of great importance. To minimize planting damage, the use of small stock and sufficient care in planting seem necessary. In either center holes or good slits, properly planted 1-0 seedlings might develop root systems near enough to the normal pattern that root rots would not become very damaging. Survival and top growth of such seedlings should also be much better than in poorly planted trees — better especially than in 2-0 stock, in which the roots are more likely to be wedged into a ball and the taproots bent into J, L, or U shapes.

These conclusions are not considered in conflict with Wakeley's (1954) statement that apprehension over ill effects from slit planting of southern pines is unwarranted. His observations were based on excavated roots and on the evident vigor of thousands of acres of pulpwood-size pines. Presumably the use of 1-0 seedlings and careful, closely supervised planting accounted for the good results he observed. Because of continued pressure to reduce costs, present-day crews may not be turning out such good-quality plantings. This inference is supported by Gruschow's (1959) survey in southeastern Virginia, where he found that only about a third of the planted seedlings appeared to be developing normal root systems.

Summary

A study was started in 1960 to compare the development of direct-seeded and planted pitch, shortleaf, and loblolly pines in southern New Jersey. The planting included 1-0 and 2-0 stock; and center-hole, good-slit, and poor-slit planting. All seeds and seedlings of each species came from one lot of seed. The direct seeding and planting of 1-0 stock were done in the spring of 1961; and 2-0 stock was put in 1 year later. In November 1962, one seedling from each plot (four of each species-treatment combination) was excavated to determine the early effects of establishment methods on root systems.

Seedlings starting in place from direct seeding had normal root systems: taproots usually penetrated vertically; laterals grew away from taproots almost at right angles and on all sides.

Seedlings planted in slits usually had one-plane root systems. Those in poor slits, which had been planted with J-, L-, or U-shaped taproots, had reacted either by the new growth of the taproot turning abruptly downward, or by another root developing to replace the taproot. Seedlings planted in good slits exhibited much less distortion of root systems, but this method did not provide the spreading root systems of center-hole planting.

In all planting methods, intertwined roots were found near the soil surface. This condition was especially conspicuous on stock planted in poor slits. Presumably some of these intertwined roots will strangle each other to death and thus provide entry for wood-decaying fungi.

Root systems of 1-0 stock showed much greater recovery from planting distortions than did those of 2-0 stock. In establishing plantations by planting, carefully planted 1-0 stock would seem to offer the most promise of developing into stands that would be relatively safe from root-rot damage. Whether they would be as resistant as stands from direct seeding is still an unresolved question.

■

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The Silvics and Silviculture of VIRGINIA PINE in Southern Maryland

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by Richard H. Fenton and Adna R. Bond

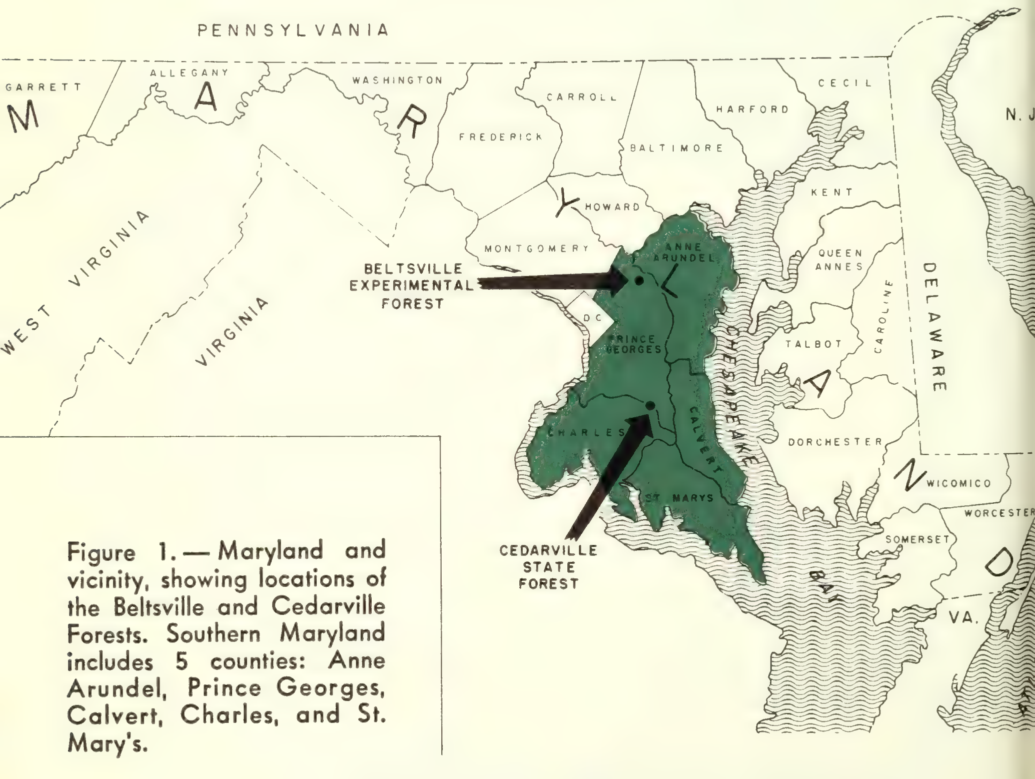

Figure 1. — Maryland and vicinity, showing locations of the Beltsville and Cedarville Forests. Southern Maryland includes 5 counties: Anne Arundel, Prince Georges, Calvert, Charles, and St. Mary's.

IMPORTANCE AND DISTRIBUTION

VIRGINIA PINE *(Pinus virginiana* Mill.) is an important forest tree in southern Maryland. The five counties south of Baltimore (fig. 1), which comprise southern Maryland, contain about 825,000 acres of commercial forest land, and Virginia pine accounts for a greater proportion of the cubic volume on this area than any other species (Banks 1953). In the lower counties, especially along the Chesapeake Bay and Potomac River, loblolly pine partially replaces Virginia pine. Elsewhere in southern Maryland, Virginia pine remains the major species.

Although its natural range extends from central Pennsylvania and central New Jersey south to Alabama (fig. 2), Virginia pine becomes of appreciable commercial importance only in fairly restricted areas where climatic conditions, soils, and past land use favor the widespread occurrence and dominance of the species. For example, the natural range covers all of Maryland except possibly Garrett County, but Virginia pine becomes a predominant and important species only in the southern portion of the State. Similarly, the commercial range of Virginia pine in North Carolina is restricted to eastern Mountain and western Piedmont Counties except for a narrow strip extending southeast along the Flat River drainage into Durham County (Slocum and Miller 1953).

Throughout its natural range, Virginia pine is often found in the pure stands that are representative of forest cover type 79, Virginia pine, as classified by the Society of American Foresters (1954). The species is also listed as a major component of two other types: type 77, shortleaf pine-Virginia pine; and type 78, Virginia pine-southern red oak. And Virginia pine is found as a component of several other forest types where its common associates include shortleaf, loblolly, and pitch pines; eastern redcedar; and numerous species of oak and other hardwoods.

Virginia pine, commonly considered one of the less desirable southern pines, first became commercially important in southern Maryland (Sterrett 1911; Besley 1916), where extensive cutting of this species was common at least 50 years ago. In recent years,

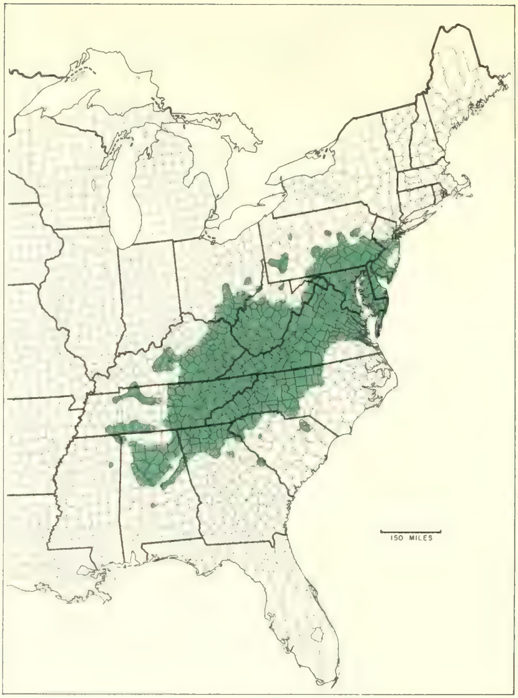

Figure 2. — The botanical range of Virginia pine. (Map prepared by Elbert L. Little, Jr., U. S. Forest Service.)

substantial volumes of Virginia pine pulpwood — about 45,000 cords annually — have been shipped from southern Maryland by truck, rail, or water to mills in Pennsylvania, Maryland, and Virginia. Many trees of this species have also been cut for lumber, piling, small poles, and, less commonly, for fuelwood and local-use Christmas trees.

During past cutting operations in southern Maryland, little consideration has been given to reproducing desirable stands. On many sites, relatively pure stands of Virginia and other pines have been replaced after cutting by less valuable pine-hardwood or hardwood stands. As a result, an increase in the proportion of softwoods would be desirable on nearly half of the commercial forest area in southern Maryland. However, poor regeneration following past cuttings has been counter-balanced to a large extent by the development of relatively pure stands on abandoned fields. Thus, in the 5-county area of southern Maryland, the current acreage in Virginia pine is about equally distributed among seedling to sapling, poletimber, and sawtimber stands according to the observations of local foresters and available forest-survey data.

Because Virginia pine is adapted to poor sites and is so abundant in southern Maryland, local foresters have sought methods to favor its reproduction and growth. Cooperative studies to provide such information have been made by the Northeastern Forest Experiment Station and Maryland Department of Forests and Parks; a few studies were made prior to World War II and many in the period 1946 to 1960. Most of this research was done on the Beltsville Experimental Forest in Prince Georges County and the Cedarville State Forest in Prince Georges and Charles Counties (fig. 1). This publication presents the knowledge gained to date from these and other pertinent studies on the silvical characteristics of Virginia pine and appropriate silvicultural methods.

SILVICAL CHARACTERISTICS

SUITABLE SOILS[1]

Virginia pine grows well on a variety of soils (Snow 1960). But this species can be considered an economically desirable forest crop only on soils that are too poor for high-quality hardwoods. In other words, only on these poor soils does Virginia pine produce a more valuable timber crop than the associated hardwoods.

Soils considered suitable for Virginia pine in southern Maryland fall chiefly into the Aura, Croom, Beltsville, Lakeland, and Galestown series. Virginia pine should also be favored on some severely eroded phases of Sassafras, Collington, Chillum, Sunnyside, and Westphalia. With the exception of the sandy Lakeland and Galestown series, these soils have characteristically sandy-clay or silty-clay substrata, sometimes cemented or compacted as in the cases of Aura, Chillum, Croom, and Beltsville. Some of these upland soils of southern Maryland tend to be droughty in summer; however, most of them retain some soil moisture in their clayey substrata throughout the year.

Interspersed with the poorer upland soils are moister, more fertile soils where high-quality oaks, yellow-poplar, or sweetgum should be grown. These hardwood sites include (1) the alluvial deposits along streams, (2) bottomland soils such as the Freneau, Bibb, and Johnston, and (3) the finer-textured, better upland soils such as Collington and Sassafras. Oaks, yellow-poplar, or sweetgum will not only produce much higher-quality timber than Virginia pine on these sites, but these hardwoods will afford such severe competition that pine cannot be economically favored.

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[1] R. M. Kirby, soil scientist of the Soil Conservation Service, U. S. Department of Agriculture, Annapolis, Md., assisted in the preparation of this section.

Virginia pine does seed in on abandoned fields of moderately well-drained to poorly-drained soils such as the Beltsville, Elkton, Leonardtown, and Shrewsbury series. However, except for the Beltsville soils, these appear capable of producing good-quality hardwoods; thus, silvicultural efforts after the initial pine crop should usually favor the hardwoods. But on the Beltsville soils, especially on severely eroded sites, a second crop containing a high proportion of pine will probably be desirable — if the most valuable timber yields are to be obtained.

Virginia pine is not adapted to very poorly-drained soils, even those composed of sands and gravels. On poorly-drained sites, loblolly, pitch, or pond pines should be favored on the coarser-textured, less fertile soils and hardwoods on the finer-textured, more productive ones.

SUCCESSIONAL ROLE

Virginia pine is definitely a pioneer species. It rapidly invades and forms nearly pure stands on old fields, borrow pits, roadside cuts and fills, and other disturbed sites (fig. 3). Severe wildfires that kill the overstory may be followed by dense reproduction of this species (Church 1955a). Some pioneer stands of predominantly Virginia pine also contain appreciable numbers of pitch, shortleaf, or loblolly pine.

In the absence of silvicultural measures, the relatively pure stands of Virginia and other pines are not reproduced, but give way to increasing amounts of hardwoods. Pine stands of sapling or pole size usually contain an understory of small hardwoods: white, black, and southern red oaks as well as hickory and dogwood are common on the drier sites; sweetgum, red maple, blackgum, holly, and bottomland oaks (such as willow and swamp chestnut) become more prevalent in the understory on the moister soils. For example, one Virginia pine stand 22 years old had 1,175 stems of oak species per acre, 150 hickory stems, and 100 stems of other hardwoods in the understory. An older stand on a moister site had an understory made up of 1,860 oaks, 1,040 red maples, 320 blackgums, 540 sweetgums, and 500 stems of other hard-

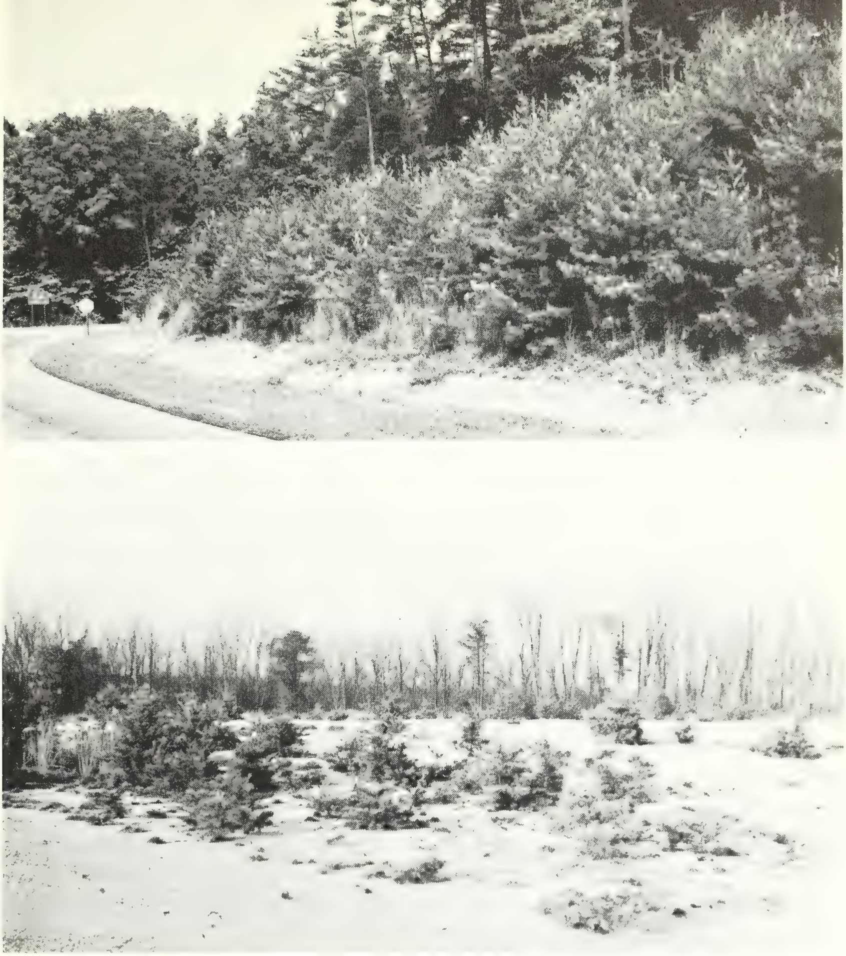

Figure 3. — Virginia pine is usually the first tree species to become established on severely disturbed sites such as this sunny roadside cut (above) or this abandoned borrow pit (below).

woods per acre. Depending on how and when the pine overstory is removed, the next crop on either site may be predominantly hardwoods or a mixture of pine and hardwoods.

Composition of the climax hardwood forest varies with soil-moisture conditions. On the drier sites, the climax should probably be classed as oak-hickory with black, southern red, and white oaks often predominating; some beech would normally occur, too. On the wetter sites, the oaks would yield to more tolerant species such as red maple, blackgum, holly, sweetbay, and beech.

SEEDING CHARACTERISTICS

Seed Production[2]

Virginia pine is a prolific producer of seed. Open-grown trees bear mature cones when only 5 years old and can continue to produce as long as they live (Sterrett 1911). In exceptionally good seed years, Virginia pine stands may shed as many as 70,000 seeds per acre on adjoining clear-cut strips (132 feet wide). Under one mature uncut stand at Cedarville, the seed catch in a 5-year period varied from a low of 48,000 per acre in 1956 to a high of 996,000 in 1957.

Although no complete failures have been observed, the size of Virginia pine seed crops fluctuates greatly from year to year. In the 11-year-period 1950 to 1960, better-than-average crops were borne at Beltsville in 5 years: 1950, 1953, 1957, 1958, and 1960. At Cedarville, where seedfall was sampled between 1956 and 1960, good crops were produced in 3 years: 1957, 1958, and 1960. Apparently there is no fixed pattern in the occurrence of good seed crops: they may be 1 to 4 years apart.

High stand density may delay cone production (Snow 1960) and also reduce the number of cones borne. Crown release stimulates cone production beginning in about the third growing season after release (Sucoff and Church 1960).

Residual stands adjacent to clear-cut strips produce substantial amounts of seed for restocking the cutover areas. At Beltsville for example, seedfall was measured on NE-SW strips cut through two mature stands with these results:

- On 3-chain-wide strips in stand A, annual seedfall was 18,000, 11,600, 6,400, and 40,000 seeds per acre during a 4-year period, an average of 19,000 per acre per year.
- On 2-chain-wide strips in stand B, annual seedfall was 14,200, 54,900, 8,200, 21,000, 70,200, 20,900, and 61,500 seeds per acre during a 7-year period, an average of nearly 36,000 per acre per year.

Scattered seed trees may rank higher in seed production than residual strips of trees. In a 45-year-old Beltsville stand, 31 seed trees per acre left after cutting produced an annual average of 102,000 seeds per acre, or 3,500 seeds per tree, over a period of 5 years. In another portion of the same stand, 11 remaining seed trees per acre produced an annual average of 92,000 seeds per acre, or 8,400 per tree, over the same 5-year period.

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[2] Numbers of seeds mentioned in this section include both sound and unsound seed.

Seed Viability

The viability of Virginia pine seed varies greatly. At Beltsville, seed viability was associated with size of seed crop. During good seed years, about 80 percent of the seed was viable; in poor seed years, only about 20 percent was viable. In 1956, an unusually poor seed year, the viability of a sample of seed was 2 percent.

Seed Distribution

In southern Maryland, seed dispersal of Virginia pine begins between mid-October and early November. Most of the seeds become viable at least 8 weeks earlier (Church and Sucoff 1960). Although dispersal continues until late May or possibly longer, 60 to more than 95 percent of the sound seeds fall before January 1. Both the beginning of seedfall and its rate differ appreciably from year to year (Sucoff and Church 1960). Dispersal is modified in occasional trees by the presence of serotinous cones that remain closed for a year or more.

Distribution of the seed is greatly influenced by the force and direction of the winds that occur on dry days during the period of heavy seed dispersal. In a 3-year study at Beltsville, the ratio among the numbers of seeds that fell on the north, east, south, and west sides of a seed source was about 2 : 4 : 4 : 1, respectively.

The amount of seedfall decreases rapidly with increased distance from the source. Traps at 100 feet from the edge of a stand commonly catch only 6 to 16 percent as many as do those at 10 feet. At 150 feet no sound seeds may be caught on the north or west sides of a good source, only about 1,000 per acre on the south side, and 2,600 on the east side (Sucoff and Church 1960).

SEEDLING ESTABLISHMENT

Seed Germination

Although the best germination of Virginia pine seed occurs on a seedbed of mineral soil, a thin layer of litter is also fairly satisfactory. Light sod, such as that found during the early stages of succession on abandoned fields, is also a suitable seedbed, but dense sod is not a favorable medium (Sterrett 1911; Bramble 1947). Sowers found very poor germination and survival of direct-seeded Virginia pine on an undisturbed heavy sod.[3]

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[3] Correspondence in the files of the Northeastern Forest Experiment Station from David W. Sowers, Jr., of the West Virginia Pulp and Paper Company.

In cutover areas, the seedling catch is usually largest in spots where the forest floor has been appreciably disturbed by logging and mineral soil has been exposed. Light winter fires that precede seedfall or controlled slash fires after logging usually improve the seedbed for Virginia pine reproduction, too. Either logging or fire disturbance may result in germination that is 2 to 4 times that found on undisturbed seedbeds and 2-year survival that is 4 times as much (Sucoff 1961b).

Seedling Survival

Virginia pine seedlings require an appreciable amount of light for good survival and growth. With low light intensities such as those found under well-stocked Virginia pine stands, few seedlings survive beyond their first growing season. Even partial shade hinders growth: although the seedlings may survive for several years, they become deformed and eventually succumb, partly because of competition from more tolerant hardwoods and shrubs (Fenton 1960) (fig. 4). For maximum growth, Virginia pine seedlings require direct sunlight.

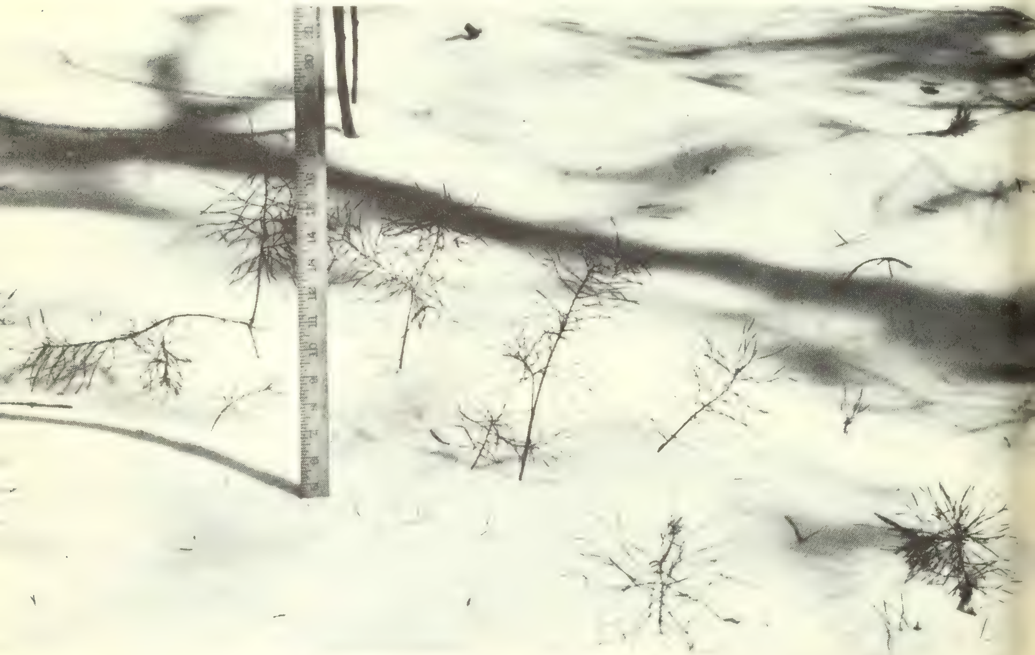


Figure 4. — Sparse foliage and stunted growth are typical of suppressed Virginia pine seedlings, like these.

GROWTH AND YIELD

Height Growth

Unhindered by competition from other species, Virginia pine seedlings on favorable seedbeds reach 4 to 8 inches in height during their first year. At 10 years of age, dominant pines on the better sites average 17 feet in height (Sterrett 1911). On most of the sites in southern Maryland, dominant Virginia pines 50 years old have heights of 55 to 70 feet; however, there are some less productive sites where the tree heights are somewhat less. The specific factors that affect the site quality for Virginia pine in this area and their relative importance are not known at present.

Like other southern yellow pines, Virginia pine often has more than one flush of height growth during a growing season. Some seedlings and older trees may exhibit only one flush, but vigorous seedlings and saplings often have 3 and sometimes 2 or 4 elongations of the terminal shoot. Height growth of these vigorous stems may not cease until early September whereas the height growth of slow-growing trees terminates much earlier. However, observations at Beltsville indicate that on most trees — even the vigorous ones—about 85 percent of the height growth occurs between mid-April and mid-June (fig. 5).

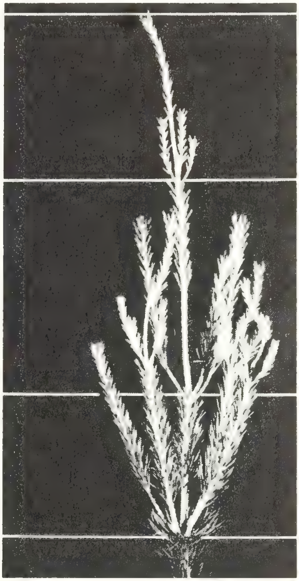


Figure 5. — By early June, three growth flushes and 84 percent of the seasonal height growth had already been completed by this vigorous Virginia pine sapling.

Mortality

Mortality is high in densely stocked Virginia pine stands partly because of rapid crown differentiation and the resulting early suppression of many stems. Seedling stands may contain 10,000 stems per acre, sapling stands about 5,000. However, in typical stands, the number dwindles to 1,000 or so at 20 years of age, to 300 at 50 years, and to about 170 stems per acre at 70 years (Church 1955b). Apparently in some stands, such as Slocum and Miller (1953) describe in North Carolina, the reduction in number of stems is slower than that reported by Church.

Volume Growth and Yield

A yield table for average site conditions in southern Maryland indicates that cubic volume increases in unmanaged stands at a fairly uniform rate until the trees are about 40 years old. By then, the average tree size is 7 to 8 inches in d.b.h. and the merchantable stand volume is about 2,800 cubic feet per acre. The volume increase becomes slower after the stands reach 40 years old; and at 70 years the average stand contains only about 3,550 cubic feet of merchantable pulpwood (Church 1955b). Because of the decline in merchantable cubic-foot growth rates after 40 years, Virginia pine stands are frequently clearcut for pulpwood shortly after they reach this age.

The effects of stand density, site, and age on the cubic-foot yields of Virginia pine have been described by Nelson, Clutter, and Chaiken (1961). These authors show that density as expressed in basal area per acre has a significant influence on final yields: for example, stands 50 years old on 65-foot sites have about 480 more cubic feet per acre at 100-percent density than at 60-percent density. Based in part on plots located in southern Maryland, these data should reasonably provide more precise estimates of growth and yield than can be obtained from Church's study mentioned above.

If grown to about 70 years of age, Virginia pine stands do produce a reasonably large cut of sawtimber; but the trees are small, usually 9 to 15 inches in d.b.h., and have coarse, persistent branches. Under standards of utilization typical of southern Maryland, these stands yield 12,000 to 15,000 board feet per acre.

Maximum Size and Longevity

Although Harlow and Harrar (1950) give the maximum size of Virginia pine as 3 feet in diameter and 100 feet tall, the largest tree recorded in Maryland was only 28 inches in diameter (Dixon 1961). Maximum heights in Maryland are usually 80 to 85 feet.

Compared to its common pine associates — shortleaf, pitch, and loblolly — Virginia pine is short-lived, seldom surviving beyond 90 years in the Beltsville area.

Pathological Rotation

Heart rots, especially by *Fomes pini,* have an important influence upon the desirable rotation age for Virginia pine under management for sawlogs. From experience at Beltsville, Fenton and Berry (1958) suggested that 70 years was the maximum desirable rotation because reductions in merchantable volume due to heart rot became excessive in older stands. However, shorter sawlog rotations may be desirable in certain areas: Slocum and Miller (1953) found that 23 to 34 percent of the trees in some North Carolina stands only 56 to 59 years old were infected by heart rot. In growing Virginia pine for pulpwood to the generally accepted rotation age of 40 to 45 years, heart rot is usually not prevalent.

DAMAGING AGENTS

Snow and Ice

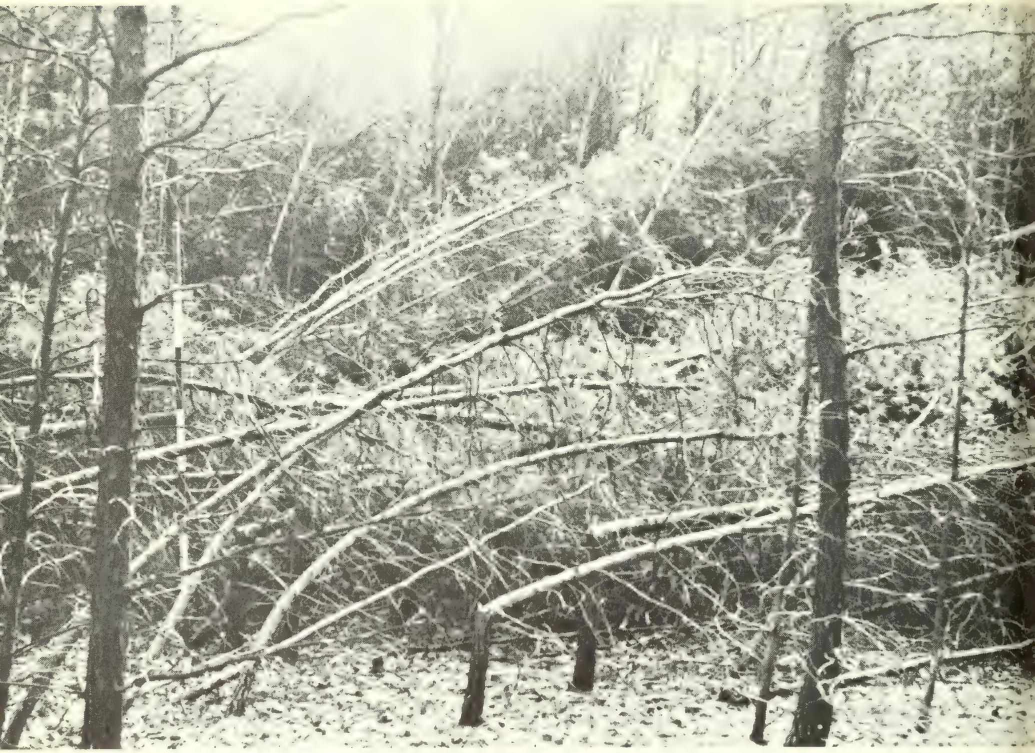
Storms that deposit wet snow or ice sometimes severely damage untreated or uncut Virginia pine stands. Reproduction 3 to 7 feet tall may be temporarily prostrated, but most of the stems usually recover. Saplings about 10 years old are more severely damaged (fig. 6); but poles and sawtimber trees generally suffer little or no damage when growing in relatively undisturbed stands (Fenton 1959).

The susceptibility of Virginia pine to snow and ice damage is considerably higher in disturbed stands than in undisturbed stands, and this fact limits the use of thinning and partial harvest cuttings. Trees of sapling size and larger are so vulnerable after release by thinning or other cutting that several authors (such as Slocum and Miller 1953) hesitate to recommend these practices.

Wind

Wind may severely damage Virginia pine stands after they have been opened up by cutting. While losses in these stands are most spectacular in hurricanes, normal winds also cause appreciable damage. For example, Hurricane Hazel in 1954, which hit the Beltsville Forest with sustained winds of 66 m.p.h. and gusts

Figure 6. — A heavy wet snow has almost completely destroyed this clump of Virginia pine saplings on the Beltsville Experimental Forest. Pole-sized trees are only slightly damaged.



of 98 m.p.h., caused losses of more than 150 cubic feet per acre in the residual stands of alternate-strip cuttings. However, normal winds produced almost equivalent losses in similar stands over a 2-year period (Fenton 1955).

Scattered seed trees are also very susceptible to wind damage. When 15 or 45 seed trees were left per acre at Beltsville, 50 and 55 percent, respectively, were lost, chiefly to windthrow over an 8-year period. On the deeper soils of the Cedarville Forest, seed-tree losses have been lower.

Fire

Virginia pine is readily killed by fire because its bark is relatively thin; young trees are particularly susceptible. The thicker bark of shortleaf, pitch, pond, or loblolly pines may at times give enough additional protection so that certain fires in mixed stands eliminate only the Virginia pines (Slocum and Miller 1953). However, in New Jersey, pole-sized Virginia pine stands have been prescribe-burned with light winter fires, and occasionally burned by light wildfires, without killing any of the overstory.

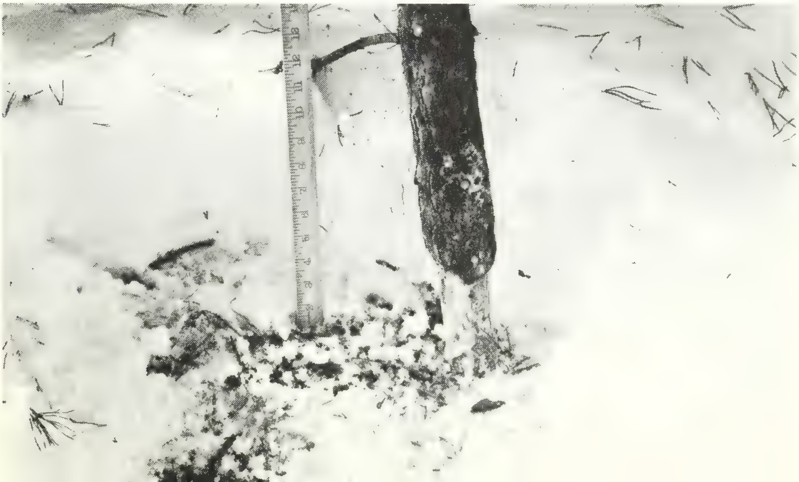
Virginia pine is also much more subject to killing by crown scorch than are associated pitch, pond, and shortleaf pines. Sapling or pole-sized stems of the latter three species that have had all their foliage killed by a fire's heat may still recover, largely because they have so many dormant buds along the boles and branches which subsequently produce new foliage. But similar damage to Virginia or loblolly pine normally kills the tree.

Virginia and loblolly pines do not sprout after the stems are killed by wildfire. In this respect, they differ from pitch, shortleaf, and pond pines. Neither Virginia nor loblolly pine retain dormant buds at the base of the stem (in the epicotyl) for more than a few years, nor do they form a basal crook in their stem. In contrast: pitch, shortleaf, and pond pines have basal dormant buds for many years; and when 1 to 9 years old (depending on how fast they grow), these pines usually form a crook at the base of the stem that often protects the basal buds by placing them in mineral soil (Little and Somes 1956 and 1960).

Animals

Deer sometimes browse the terminal shoots of Virginia pine seedlings, and rabbits may clip off the shoots of the smaller seedlings, especially those only 0.5 foot to 2 feet tall. But little reproduction is killed by either deer or rabbits because the seedlings

Figure 7. — When the environment provides favorable rodent cover, mice may completely girdle young Virginia pines.



frequently recover from browsing injury — often by developing new shoots from the needle fascicles. However, if the damage is extremely low — severing the stem at the hypocotyl — no buds will remain as sources for shoot development and the seedling will not recover.

Mice, especially meadow-mice, have been the most damaging animals to Virginia pine reproduction in the Beltsville area. Where a thick, matted cover of grasses and weeds has provided an attractive environment, mice have often been highly destructive of natural or planted seedlings. The damage, usually confined to winter, is done by chewing enough inner bark to girdle the tree (fig. 7). Probably because of thinner bark, Virginia pine seedlings generally suffer more damage than loblolly and pitch pines (Church 1954). In a 6-year-old mixed planting, 33 percent of the Virginia pines were completely girdled and 27 percent were partially girdled compared to 3 and 15 percent, respectively, of the loblolly pines (Fenton 1962).

Disease and Insects

From an economic standpoint, *Fomes pini* is the most important fungus that attacks Virginia pine in southern Maryland. Minor diseases of Virginia pine in this area include the globose gall rust *(Cronartium cerebrum)* and witches' broom. Even though the globose gall rust causes some deformity to both branches and stems as well as some mortality, it is of little importance. Other diseases that attack Virginia pine, including a root rot *(Fomes annosus)* and a butt rot *(Polyporus schweinitzii)*, have so far been of little consequence in southern Maryland.

The most serious insect pest has been the Virginia pine sawfly *(Neodiprion pratti pratti)*, which in several recent years has had a high population level in southern Maryland (McIntyre 1960). Severe and repeated defoliation by this sawfly can cause some loss of growth and scattered mortality in Virginia pine. The Nantucket tip moth *(Rhyacionia frustrana)* annually infests some of the terminal growth, especially of open-grown reproduction, but generally has little lasting effect on growth or form. Probably of greater importance than the tip moth are the bark beetles, both the southern pine beetle *(Dendroctonus frontalis)* and *Ips* spp., because these kill scattered stems or small clumps of merchantable-sized trees. In cutover areas, pales weevil *(Hylobius pales)* may kill advance pine reproduction or freshly planted seedlings; but to date damage by this weevil has not been conspicuous in southern Maryland.

SUMMARY: SILVICS

The silvical characteristics that form the basis for the silviculture and management of Virginia pine can be summarized as follows:

- Virginia pine is an intolerant tree, adapted to relatively poor soils and unable to compete successfully with associated hardwoods in the absence of severe disturbances.
- It is prolific, producing at least small seed crops annually and heavy crops at irregular intervals.
- Natural reproduction in adequate amounts is limited to disturbed sites near and especially to the leeward of good seed sources.
- Virginia pine stands are subject to damage by fire and, when partially cut, to damage by ice, snow, and wind.
- The stands are relatively free of serious insect pests or diseases, except for heart rots.
- Virginia pine is primarily a pulpwood species because of small size, coarse and persistent branches, and susceptibility to heart rot at a fairly young age.

With these characteristics in mind, let us consider what has been learned in southern Maryland from the silvicultural treatments tried in the Beltsville and Cedarville Forests.

SILVICULTURAL TREATMENTS

HARVEST CUTTINGS

Because of Virginia pine's intolerance, inability to cope with hardwood competition, and susceptibility to damage by wind, snow, and ice, some form of even-aged silviculture seems essential for perpetuating this species. And because of the high risk of damage to residual seed sources from climatic elements, the appropriate silvicultural method should provide for rapid regeneration followed by prompt removal of the residual stand. Variations in harvest cuttings that have been tried at Beltsville or Cedarville include (1) clearcutting of strips, (2) clearcutting of patches, and (3) seed-tree cuttings.

Strip Clearcuttings

Two stands of predominantly Virginia pine, 45 and 70 years old, were harvested at Beltsville by clearcutting strips 2 or 3 chains wide, respectively, separated by residual strips 1 chain wide (fig. 8). Both stands were over 30 acres in size, and the strip cuttings on both were about 20 chains long.

Even though the slash on the cutover strips in both stands was broadcast-burned in late summer, and even though trees in the uncut strips shed large amounts of seed on the cutover areas, the amount of pine reproduction was surprisingly low. Two years after cutting there were only 1,350 and 1,000 pine seedlings per acre on the cutover strips of the 45- and 70-year-old stands, respectively, which provided a stocking of 39 and 50 percent based upon milacre quadrats.

Despite the poisoning of hardwoods over 2 inches in d.b.h. at the time of cutting, the cutover strips after 2 years contained 3,600 and 6,300 hardwood stems per acre for the younger and older stands, respectively, which stocked at least 95 percent of the quadrats. Most of these hardwoods were small seedlings, but more than half of them were taller than the associated pine reproduction.

Similar strip cuttings at the Cedarville Forest have been considerably more successful than at Beltsville. Usually the Cedarville

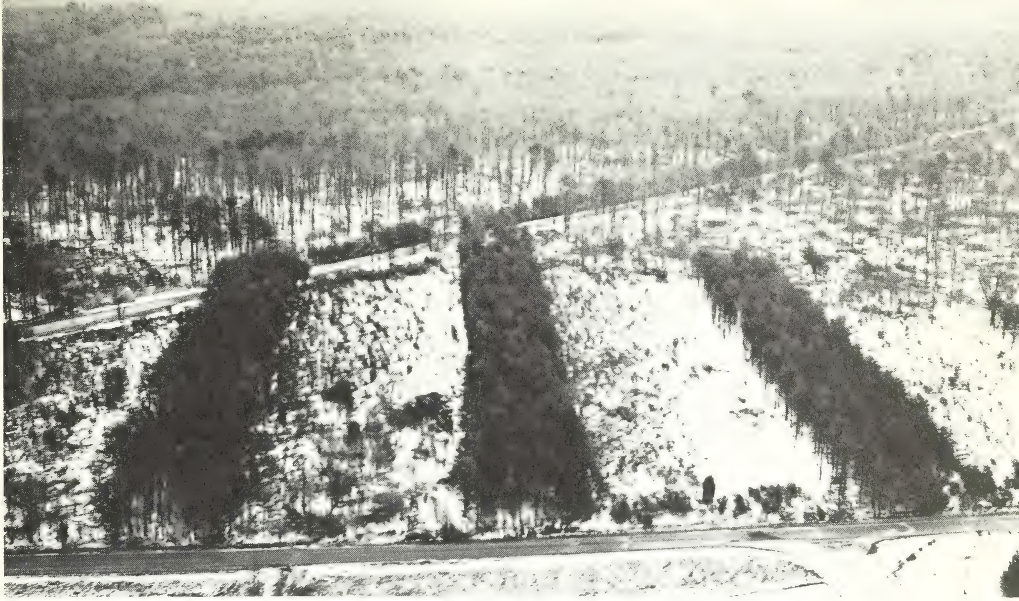


Figure 8. — Aerial view of an alternate-strip cutting in Virginia pine on the Beltsville Experimental Forest.

cuttings have provided 5,000 to 10,000 pine seedlings per acre, stocking 85 percent or more of the quadrats. However, the range in reproduction has been from 2,200 to 16,000 seedlings per acre within 5 years after cutting. With less advance hardwood reproduction than on the Beltsville cuttings, the Cedarville areas have also provided much less hardwood competition for the pine reproduction. A possible reason for the differences in hardwood competition is that the Cedarville soils are lighter and drier than those on the Beltsville Forest.

The system of clearcutting alternate strips presents problems with regard to wind damage in the residual stands and the establishment of reproduction in the leave strips. Wind damage can be reduced by leaving relatively wide strips of residual trees and then removing these trees as soon as adequate regeneration is assured, probably after 1 or 2 years when seed trees are to be kept on the leave strips as supplemental seed sources.

For the adequate regeneration of leave strips, Sucoff (1961a) recommended: (1) burning the uncut strips once before seedfall in September or early October, and then (2) harvesting these strips 1 or 2 years later, so that seed from 2 or 3 crops would supply advance or subsequent reproduction. Any fire-killed pines would still be merchantable at the time of the final harvest.

Unfortunately this procedure was never tested at Beltsville: stands on the leave strips were clearcut in October just before a good crop of seed started to fall, but with no prior seedbed preparation. Results on the cutover leave strips were fair, about the same as on the original cutover strips: 1,050 pine seedlings per acre stocking 47 percent of the milacre quadrats with about 4,300 competing hardwood stems per acre.

More pine reproduction was obtained in the Cedarville Forest than in the Beltsville Forest following harvesting of the leave strips, possibly because a few seed trees were left either singly or in small groups (fig. 9). In the first year after cutting, these cutover leave strips had 4,000 to 4,500 seedlings per acre stocking 85 percent or more of the quadrats.

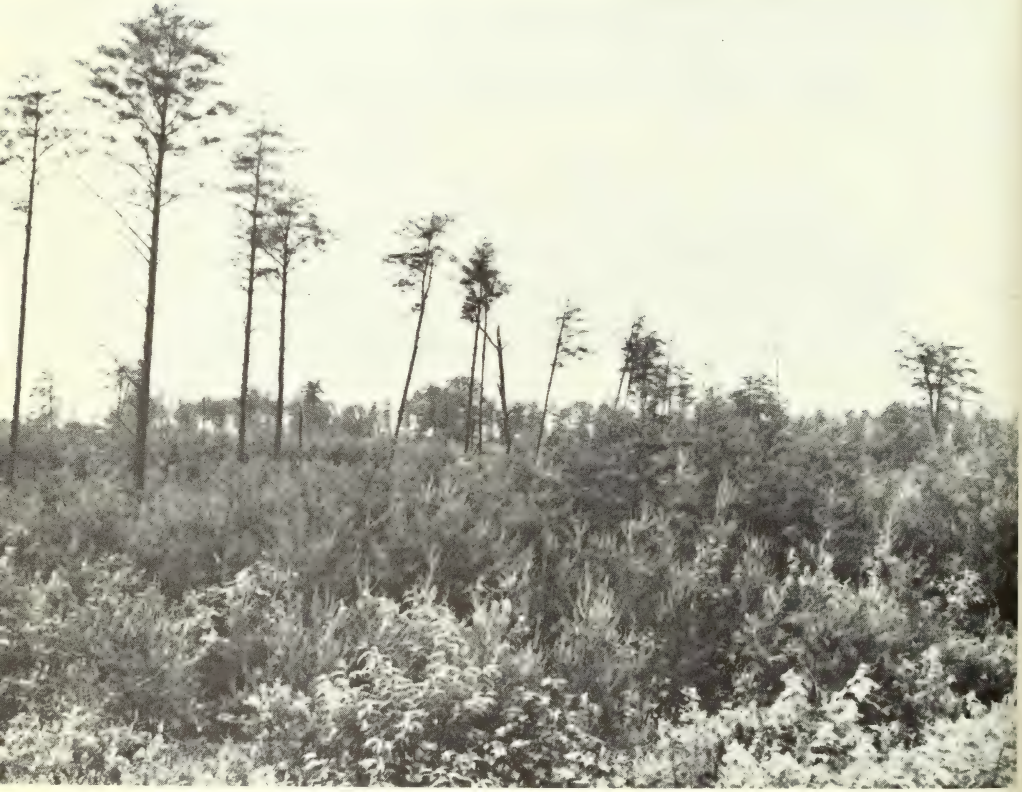


Figure 9. — In alternate-strip cuttings on the Cedarville Forest, reproduction in the final strips was obtained by leaving a few small groups of seed trees when these strips were cut.

The alternate-strip method of harvest cutting has, or may have, two drawbacks:

- Residual strips may suffer appreciable losses, up to about 30 percent of the stems in the Beltsville strips in the 4 to 6 years before the final harvest. Most of these losses are from wind damage. Reducing the interval between cuts to 1 or 2 years would materially decrease the windthrow losses.
- To obtain desirable amounts of pine reproduction on the leave strips, clearcutting of the leave strips probably must be restricted to the late summer and early fall of good seed years, or some seed trees should be left after cutting each strip.

Patch Clearcuttings

In the Beltsville Forest, the clearcutting of square patches, each of about 1/3 acre, was tried in mature Virginia pine stands during a 6-year period. Cutting was done in the winter, the slash was broadcast-burned, and the residual hardwoods larger than 2 inches d.b.h. were poisoned in the following summer. In all patches, pine reproduction outnumbered hardwood seedlings and sprouts 2 or 3 years after cutting; there were about 8,000 pines to 3,400 hardwoods per acre (fig. 10).

Patch cuttings in pine-hardwood stands were markedly less successful than in pure pine. These cuttings were of two types: (1) 1/4-acre areas were clearcut and residual hardwoods larger than 2 inches d.b.h. were killed by chemical applications, and (2) 1-acre

Figure 10. — Most small patch cuttings in pure pine, followed by prescribed burning for slash disposal and seedbed preparation, reproduce well to Virginia pine. Seven growing seasons have elapsed since this patch on the Beltsville Experimental Forest was clearcut.

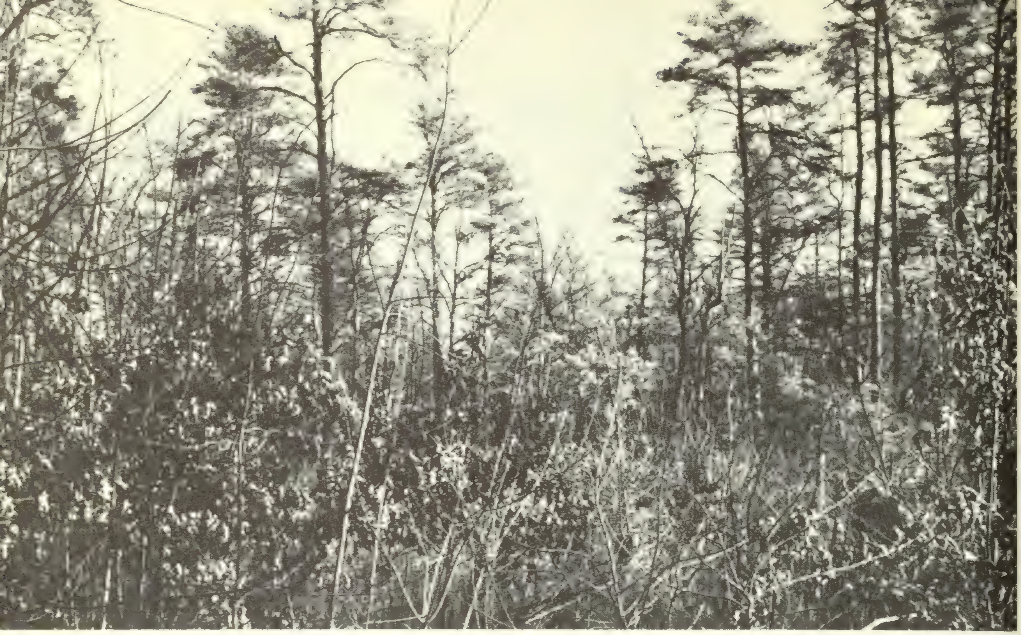


Figure 11. — Because no seedbed treatments were applied in this small patch cutting on the Beltsville Experimental Forest, pine reproduction is wholly inadequate. Hardwoods are taking over the site even though a good seed source is nearby.

areas were treated with a shelterwood cutting that removed about 40 percent of the merchantable volume. In both types of patch cuttings, pine seed trees were left if present or the patches were located on the edge of a pine seed source. Because no seedbed treatments were applied, little pine reproduction was obtained even though pine seedfall amounted to 30,000 seeds per acre annually in the 1/4-acre patches (fig. 11). Two years after cutting, the 1/4-acre patches had only 250 pine seedlings per acre, and the 1-acre patches had hardly any.

Patch clearcuttings in mature pine stands provide more seed than alternate-strip cuttings and, when aided by seedbed treatments, more pine reproduction as well. For example, in one good seed year when alternate cutover strips were receiving 70,000 seeds per acre from the residual pines on leave strips, clearcut patches in a similar pine stand were getting 300,000 seeds per acre.

However, scattered patch cuttings do have serious biological and economic disadvantages. Reproduction within a patch is shaded to some extent by the adjoining older timber and, particularly on the edge of the patch, conditions more favorable for hard-

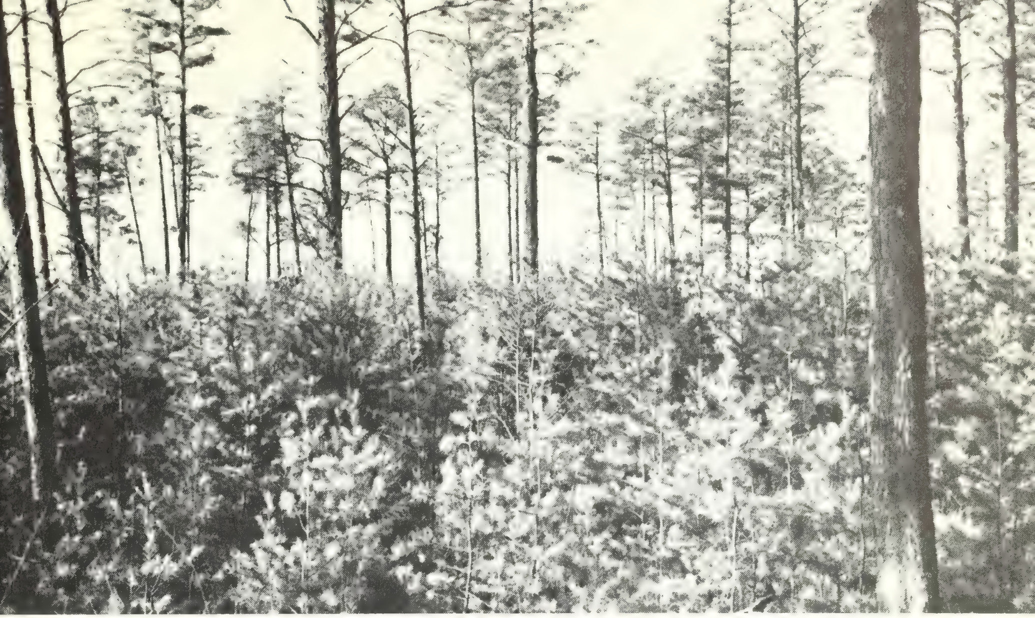


Figure 12. — Forty-five pine seed trees per acre were retained in this cutting on the Beltsville Experimental Forest, which has adequately regenerated to Virginia pine. But an adjacent cutting leaving only 15 seed trees per acre resulted in equally good regeneration and smaller losses of seed trees due to windthrow.

woods than for pines are created. With patches only 1/3 acre in size, edge effects prevail over a large portion of the total stand.

Even more serious are the economic disadvantages. In the first place, such small units are expensive to log. In fact, several nearby units would have to be cut at the same time to provide a logging chance of interest to a commercial logger; and even then, the stumpage value paid to the owner would usually be less than in larger areas. Furthermore, small scattered units result in expensive cultural operations and costly, inefficient bookkeeping. In all these ways, returns to the timber grower would be markedly reduced.

Seed-Tree Cuttings

Several variations of seed-tree cuttings were tried in pure pine stands of the Beltsville Forest. These differed chiefly in the number of seed trees left; the numbers tested were 5, 15, 25, 40, and 45 seed trees per acre (fig. 12).

Fifteen trees per acre provided a sufficient amount of seed for satisfactory regeneration on favorable seedbeds — 4,600 seedlings per acre stocking 80 percent of the quadrats. Certainly 40 or 45 trees are unnecessary for seed supply. Whether fewer than 15 trees would be adequate is questionable, since their effectiveness varies greatly with size of seed crop, seedbed conditions, and weather conditions during germination and early growth of the seedlings.

Seed trees should be salvaged within a year or so after an adequate amount of pine reproduction is established, or they should be considered as a probable loss on many sites. While the Beltsville cuttings were made under the assumption that the seed trees would survive a subsequent 40-year pulpwood rotation and become quality sawtimber, that assumption proved false. The experience at Beltsville indicates that, in such a period, probably far more than half of these trees would be lost to windthrow, wind breakage, and lightning. In contrast, the deeper-rooted trees left after seed-tree cuttings in the Cedarville Forest usually have had a low mortality rate; but even here the short longevity of Virginia pine will probably not permit the survival of many seed trees through a subsequent pulpwood rotation.

Seed-tree cuttings in pine-hardwood stands gave far less favorable results in securing pine reproduction than did similar cuttings in pine stands. The fault was not in seed production: where 25 pines per acre were left as seed trees after cutting one pine-hardwood stand, seedfall varied from 32,000 to 285,000 seeds per acre annually, or an average over a 4-year period of 121,000. However, hardly any pine reproduction was obtained, because (1) no seedbed treatments were made, and (2) hardwood associates were not adequately controlled.

Other Harvest Cutting Methods

Other possible cutting methods, untried as yet, that might favor the perpetuation of Virginia pine include:

- *Progressive strip cuttings* that start on the south or east side of a stand and progress toward the north or west. With only a year or so between the cutting of adjoining strips, much of the damage from windthrow or wind breakage could be salvaged. In the final strip, as in the Cedarville strip cuttings, seed trees could be left temporarily either singly or in clumps for reseeding. Chief advantages of the progressive strips over alternate strips seem to be: (1) reduced importance of wind damage due to the good opportunities for timely salvage; and (2) in large areas, cutting could be almost continuous since far less reliance is necessary on good seed crops. However, when exceptionally poor cone crops provide small amounts of new reproduction — 1,200 or fewer seedlings per acre — seed trees should be left along the nearest border of the next strip. After a year, these seed trees could be removed during the course of a regular harvesting operation.

- *Shelterwood cuttings* in which possibly half of the stand is cut, followed either by a slash burn or the use of a heavy disk for seedbed preparation. As soon as adequate amounts of pine reproduction had become established, probably in 1 or 2 years, removal of the residual stand would be necessary. However, after the second cut, damage by pales weevil could be excessive —although we have little direct information on this possibility. If serious, such damage could prevent shelterwood cutting from becoming an effective means for reproducing Virginia pine — unless a feasible method of weevil control were developed.

Recommended Methods

For (1) effectiveness in reproducing Virginia pine, (2) feasibility under long-term management, and (3) stumpage returns, the use of seed-tree cuttings in most stands and of progressive strip cuttings (with seed trees in the last strip) in especially extensive stands seems most logical. Where seed trees are left, they may be retained in small clumps and in locations favoring their easy removal, but they should be salvaged where economically feasible as soon as adequate amounts of reproduction become established. An alternative would be: (1) to remove the seed trees after seedfall in the year following the initial cutting, and (2) in 1 or 2 years, to plant any gaps appearing in the pine reproduction. In planting, loblolly pine seedlings might well be chosen in preference to Virginia pine (see later section on conversion to other pines).

SUPPLEMENTAL REGENERATION MEASURES

Seedbed Preparation

Seedbed preparation is essential in both pure pine and pine-hardwood stands if adequate amounts of Virginia pine reproduction are to be established. Both at Beltsville and Cedarville, regeneration was inadequate where no seedbed preparation measures were applied. But where the seedbed was sufficiently disturbed prior to seedfall, the amount of regeneration varied from barely adequate to highly satisfactory. Sufficiently disturbed seedbeds do not guarantee reproduction, because good seed sources are also necessary; however, they do greatly increase the chances of success from a given amount of available seed.

Final evaluation of the different possible methods for seedbed preparation is not justified at present, but the following comparative statements can be made:

- *Broadcast summer burning of well-cured slash* prepares a highly favorable seedbed and reduces competition from shrubs and small hardwoods. It is most applicable on strip clearcuttings (fig. 13).[4] In seed-tree cuttings, slash should be kept away from the seed trees, and even then an appreciable number of seed trees may be killed. For best results, burning should be done in late summer or early fall, preferably between mid-August and mid-October.

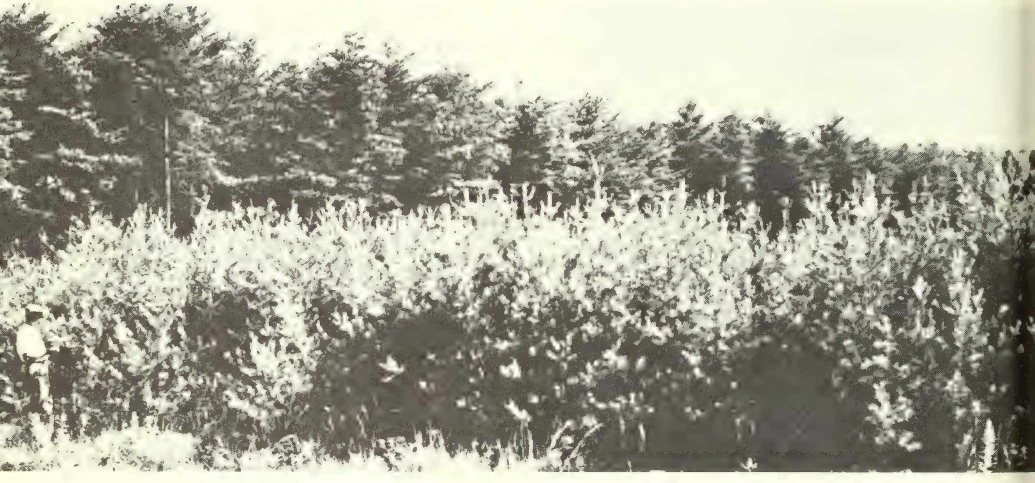


Figure 13. — Excellent Virginia pine reproduction that started on a clearcut strip on the Beltsville Experimental Forest after the slash was broadcast-burned.

- *Light fires under stands* may not be applicable in the Virginia pine areas of southern Maryland. Presumably if these fires could be used in cool fall or winter periods, they might prepare the seedbed and favor the establishment of advance pine reproduction without damaging overstory pines. However, in pure pine stands, such fires are not easily applied because of the thin, relatively compact fuel, which does not burn readily except under dry and rather hazardous conditions. For example, an early September fire under one stand was relatively successful in that it resulted in the establishment of 3,000 Virginia pine seedlings in the first year after burning and 7,800 by the fourth year — nearly 4 times the number on an unburned seedbed; but 54 percent of the Virginia pine overstory was killed after 1 year, 67 percent within 2 years, and all by the end of 4 years. Because of the obvious difficulties of providing the proper type of fire as well as the possibility of pales weevil damage to advance reproduction, the use of such fires is regarded as experimental at present in Virginia pine stands (and probably most applicable where hardwood leaves are an important part of the litter).

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[4] As a standard logging practice, both at Cedarville and Beltsville, operators have been required to fell the trees so that the tops land toward the center of the strip being harvested.

- *Disking* with a D4 tractor and heavy Rome disk is a third possibility, but also of limited value at present. To date, the only machinery treatments tried in southern Maryland have been with an impractical garden tractor on small plots. Furthermore, a tractor and disk of sufficient size to be feasible in seedbed preparation require room to maneuver, so their practical use would be limited to clearcut areas or to stands where 50 percent or more of the stems had been cut. Because slash and stumps limit the effectiveness of machinery, disking seems to be largely a supplement to burning — to be used in areas where burning is not feasible. Probably the most appropriate areas would be in pine-hardwood stands where the cutting may create relatively little slash.

Of the three alternatives, slash burning after cutting has so far proved to be the most feasible form of seedbed preparation. This burning has cost between $5 and $15 per acre.

Control of Competing Vegetation

Because established hardwood understories are not eliminated by logging or seedbed treatments, further control work is needed on most areas if Virginia pine reproduction is to become dominant. In the past, some release by cutting overtopping hardwoods has been applied, but this is relatively expensive. For example, in the Beltsville Forest such release took 12 man-hours per acre. Even though it was effective, less time-consuming methods are now available.

Mistblower applications of small quantities of herbicide have proved effective for the selective release of other pine species and should be tried in the Virginia pine stands of southern Maryland. The following formulation should be suitable: 2 pounds acid equivalent of the isooctyl ester of 2,4,5-T in an oil-water carrier of 2 quarts of No. 2 fuel oil in 4 gallons of water. This formulation has worked satisfactorily for releasing loblolly and pond pines in eastern Maryland and pitch and shortleaf pines in southern New Jersey. Probably 2 to 5 gallons of spray should be applied per acre, the amount depending upon the density and size of the competing stems. Summer treatments applied before mid-August would probably produce the best results, provided that applications were not made during droughty periods. And care must be taken to avoid drift damage (Little 1963b).

In many stands, some large cull hardwoods may be left after logging, and these should usually be killed. While various methods are possible, treatment with a tree injector that uses small amounts of chemical and carrier seems to be one of the best. For the mixed species common in southern Maryland, the following procedure is recommended:

- Use an ester formulation of 2,4,5-T at a concentration of 80 pounds ahg (acid equivalent per 100 gallons of mixture) in oil.
- Apply about 2 milliliters of the solution per cut.
- Make cuts join to form a complete frill. Keep them low to reduce sprouting (Little 1963a).

In areas where some of the hardwood understory survives mistblowing in sufficient numbers to be a problem, a similar injector treatment is recommended for these smaller stems as well as the large culls.

The need for releasing Virginia pine reproduction after cutting could be avoided to a large extent by the use of conditioning treatments that set back or eliminate competing understory stems prior to harvest cutting. Trials in eastern Maryland and southern New Jersey indicate that mistblower treatments with certain formulations of 2,4,5-T offer the most promise and thus should be tested in southern Maryland.

The most promising formulations for early-season use include the isooctyl ester, the butoxy ethanol ester for aerial application, and the butoxy ethoxy propanol ester, all of these in oil-water carriers. For late-season use, the most promising chemical is the butoxy ethanol ester formulated for an oil carrier. Oil-water treatments would probably be effective from late May through July;

but in August the oil carrier should be used. For most Virginia pine stands, 2 pounds of acid in 4 or 5 gallons of spray per acre will probably be adequate. Again, extreme care should be taken to avoid drift damage outside of the treated area (Little 1963b). And in view of the density of Virginia pine stands, treatments might have to be made with back-pack rather than tractor-mounted machines.

These recommendations on the use of mistblowers for controlling competing vegetation by release or conditioning treatments still need to be tested in southern Maryland; but, although tentative, they are unquestionably more appropriate than any suggestions based upon the early manual and chemical treatments used in the Beltsville studies.

TREATING IMMATURE STANDS

Thinning

According to the limited available information, thinnings in Virginia pine stands appear to hold some promise only when restricted to relatively young stands and when sufficient numbers of trainers are retained. This deduction is based in part on a study established in the Cedarville Forest in 1938, which involved reductions in stand density of 50 to 75 percent in 15-, 25-, and 30-year-old pure Virginia pine stands. In the first 10 years, Rushmore[5] found that:

- The three age classes showed about equal responses in radial growth, and the radial growth of released crop trees was greater than that of non-released crop trees as shown below:

Stand age (years)	*10-year radial growth (inches at breast height)*		
	Released trees	*Unreleased trees*	*Difference*
15	1.10	0.70	0.40
25	.85	.50	.35
30	.70	.30	.40

- A heavy glaze storm caused fewer losses among the older crop trees in treatments where trainers had been left than where no trainers were saved.

Rushmore also concluded that heavy thinnings stimulated the growth of the hardwood understory (fig. 14).

Two later thinning studies were established in 7- and 17-year-old Virginia pine stands at Cedarville; in both, the thinning treat-

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[5] Rushmore, F. M. Thinning Virginia pine in Maryland — a 10-year experience. 1949. (Unpublished report, Northeast. Forest Expt. Sta.)

Figure 14. — Heavy thinnings in young Virginia pine stands will stimulate growth of a hardwood understory: Above, a pole-sized stand after thinning to 800 stems per acre. Below, the same view after 5 growing seasons.

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ment reduced the number of stems to 900 per acre from 9,000 and 2,700 stems, respectively. Results in the first 5 years were as follows:

- Stimulation of diameter growth was the same in both age classes:

	5-year d.b.h. growth (inches)		
Age (years)	*Released crop trees*	*Unreleased crop trees*	*Difference*
7	1.6	1.2	0.4
17	1.0	.6	.4

- While relatively few of the crop trees released at 7 years were lost to wind, ice, and snow, losses among those in the 17-year-old stand amounted to 20 percent in the 5-year period. Hence, basal-area growth of crop trees per acre in the 17-year-old stand was almost the same for the released and unreleased stems. In contrast, the basal-area increase of crop trees per acre in the 7-year-old stand was 21 percent greater for the released stems than for the unreleased stems.

At present it seems inadvisable to recommend thinnings in Virginia pine stands for these reasons:

- While commercial thinnings might be feasible in 20- to 30-year-old stands, the growth per acre of residual crop trees in such stands is often negligible because of losses from wind, snow, or ice.

- Although thinning in young noncommercial stands should produce an appreciable crop-tree response and result in little wind, snow, or ice damage, the effect of such a thinning on final yields is not known. Hence the investment in non-commerical thinning is of questionable value.

Pruning

Because Virginia pine retains its dead branches for an extremely long period (fig. 15), artificial pruning has sometimes been suggested for crop trees of this species.

In one study, Williamson (1953) determined the effects on diameter and height growth of removing about 38 percent of the

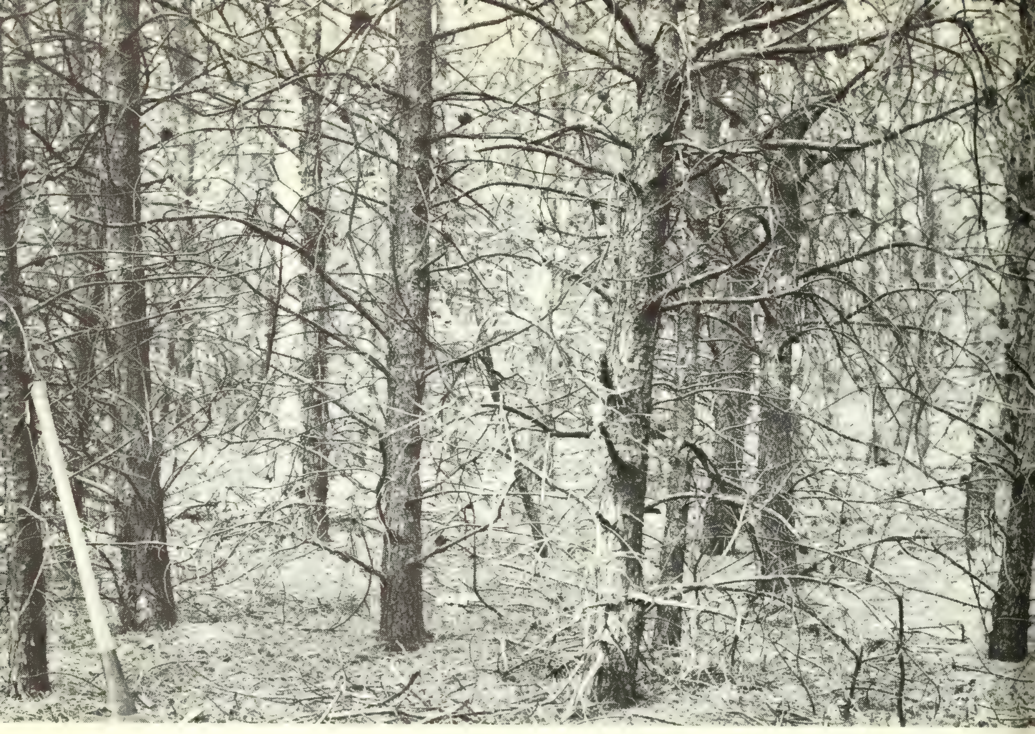

Figure 15. — Virginia pine typically has many persistent limbs. To produce clear wood, artificial pruning is necessary.

live crown of 9-year-old crop trees of Virginia pine. The four tested treatments consisted of pruning to about 8 feet above ground, release by light thinning, a combination of pruning and release, and a control. His results were as follows:

Treatment	*5-year growth* D.b.h. (inches)	*5-year growth* Height (feet)
None	1.4	10.9
Pruned	1.2	10.8
Released	1.9	11.0
Pruned and released	1.7	10.8

As might be expected, the thinning stimulated diameter growth, while pruning slightly reduced it. Neither treatment had any appreciable effect on height growth.

A more radical type of pruning, bud-pruning, has also been tried on Virginia pine with poor results. Because this method prevented the development of branches, it reduced diameter growth by 60 percent and height growth by 25 percent. It also caused severe crook or sweep in 52 percent more of the pruned trees than of the unpruned. Consequently, bud-pruning of Virginia pine is not recommended (Sucoff 1963).

In fact, it is doubtful whether any pruning of Virginia pine is justified. If the species is grown for pulpwood, pruning is obviously not needed. And if sawtimber is the desired product, conversion of Virginia pine stands at the end of the rotation to other species will probably pay greater dividends than pruning.

CONVERSION TO OTHER PINES

The associated pine species are more desirable for sawtimber than Virginia pine. Loblolly and shortleaf pines in particular, as well as pitch and pond pines in fairly dense stands, develop much longer clear lengths than Virginia pine. These associated species also grow to greater ages and — especially loblolly and shortleaf — to greater diameters as well with smaller losses due to heart rot than Virginia pine.

Height growth of Virginia pine is comparable to that of shortleaf, pitch, or pond pines on most sites; but Virginia pines are usually 10 to 15 feet shorter than loblolly at 50 years. Only on the poorest soils, where the site index for loblolly is less than 60 feet, does Virginia pine grow as rapidly in height as loblolly pine. Examples of this are the Croom and Aura soils, which have gravelly compacted substrata. Soils more suited to loblolly pine include Sunnyside, Caroline, Lakeland, Galestown, and coarse-textured Sassafras. On these, loblolly usually has a site index of 75 to 85 feet.

So, the replacement of Virginia pine with loblolly pine seems desirable in much of southern Maryland. Though the conversion would be especially desirable for the production of piling and sawtimber, even pulpwood production might be improved. In North Carolina, Miller (1954) found that loblolly pine stands were growing 117 cubic feet per acre annually compared to 92 cubic feet for Virginia pine stands on comparable sites. Observations in southern Maryland indicate that similar differences occur there.

Actual conversion methods will vary with stand conditions. In areas lacking a loblolly pine seed source, the common method is to plant 600 to 800 loblolly pine seedlings per acre the first winter or spring after existing overstories are cut (fig. 16). Where loblolly pines of cone-bearing size occur, their retention as seed trees, along with removal of the Virginia pines, will increase the propor-

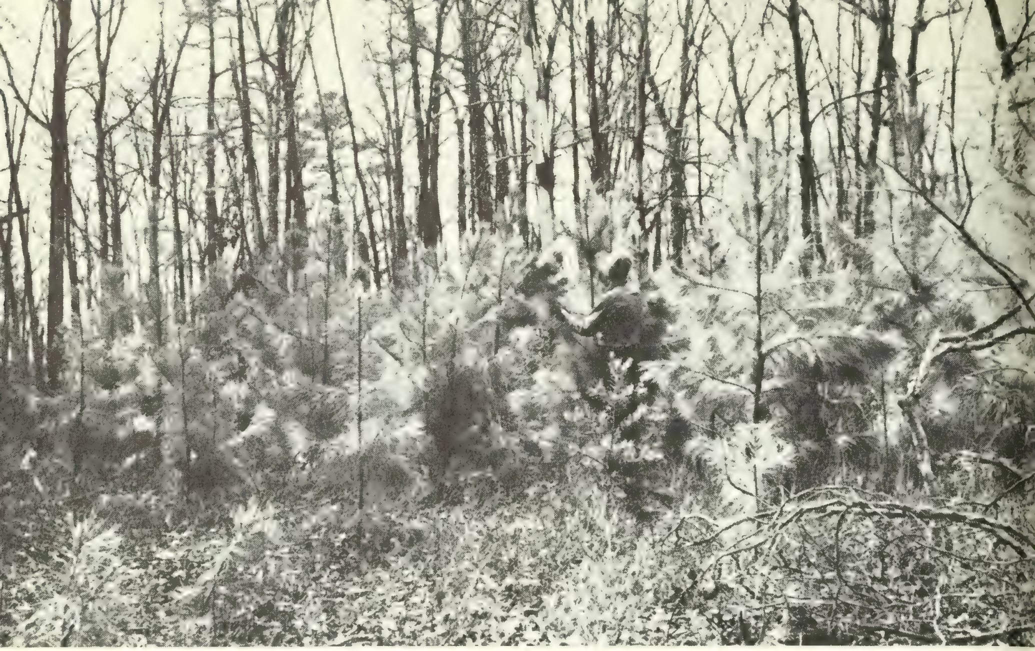

Figure 16.—Loblolly pines (1-0) were planted about 8 feet apart in this clearcut patch of a pine-hardwood stand at Beltsville. After three growing seasons, some of the loblolly pines were more than 8 feet tall.

tion of loblolly pine in the reproduction. Total elimination of Virginia pine is not recommended, but the conversion operation should provide a sufficient number of loblolly pines to dominate the next stand.

The extent to which loblolly pine should be favored in the upper portions of Prince Georges and Anne Arundel Counties is questionable. On some sites, loblolly pine might possibly suffer so much repeated winter injury that its long-term growth could be reduced almost to that of Virginia and shortleaf pines. However, some of the loblolly plantations in these two counties appear promising: one 30-year-old plantation in upper Anne Arundel County has dominant trees 12 to 14 inches d.b.h. and 70 to 78 feet tall; another 50-year-old plantation near Bowie, Prince Georges County, has dominant stems of similar diameters and 71 to 84 feet tall.

White pine offers great promise as an alternative species in the upper portions of the 5-county area — from the Cedarville Forest to the Piedmont. The occasional white pine plantations established so far in that area have shown good growth. For example, one 30-year-old plantation in the Cedarville Forest has 233 stems per acre; these stems average 12.5 inches in diameter and 60 feet in height. A comparison of dominant stems among this white pine plantation, an adjacent plantation of loblolly pine, and an adjoining natural stand of Virginia pine — all on similar soils — is given below:

Stand	*Age of stand (years)*	*D.b.h. (inches)*	*Height (feet)*
White pine	30	14-16	69-78
Loblolly pine	28	10-12	66-76
Virginia pine	45	9-11	62-71

Although white pine in upper southern Maryland compares favorably with loblolly pine, extensive plantings are not recommended at the present time. In the first place, too little is known about the growth of planted white pine in relation to site factors and about possible disease or insect problems that may arise. Then, too, white pine's growth in the first 3 to 5 years after planting is slow; and wherever a Virginia pine seed source is nearby, the planted white pines will need release from overtopping Virginia pine reproduction. In contrast, loblolly pine can usually compete successfully with volunteer Virginia pine reproduction, so investment costs for release are not necessary.

SUMMARY: SILVICULTURE

To reproduce Virginia pine, cuttings that create even-aged stands are essential. Alternate-strip cuttings have been successful in the Cedarville State Forest, where seed trees were used to regenerate the final strips, and partly successful at Beltsville. Seed-tree cuttings have been uniformly successful; and in extensive stands, some type of progressive strip cutting is a promising alternative.

Under any method of cutting, seedbed preparation is essential for adequate reproduction. To date, the broadcast burning of slash prior to seedfall has proved to be the most effective and feasible method.

Another necessary step is the control of competing hardwoods. Recommended methods are injector treatments of large, individual trees and mistblower treatments of small stems. While the latter may be applied for selective release in the reproduction stage, conditioning treatments before the harvest cutting seem even more desirable.

At present, thinning and pruning are not recommended for Virginia pine stands. Thinning, although it produces some growth response in fairly young stands, is of unproven long-term value. Pruning is of little benefit in pulpwood production; and for sawtimber production, conversion to other species appears to be a more promising alternative.

Many Virginia pine sites in southern Maryland should be converted to loblolly pine, which grows faster and produces higher-quality piling and sawtimber than Virginia pine. In the upper counties of southern Maryland, some conversion of Virginia pine stands to white pine also seems highly desirable although large-scale plantings of white pine are not recommended at present.

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Timber Industry OPPORTUNITIES in selected areas of West Virginia

Perry R. Hagenstein

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Timber Industry OPPORTUNITIES in selected areas of West Virginia

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Introduction

FIRMS in the major wood-using industries are constantly searching for new plant locations. Industrial development and promotion agencies play an important role in this search by providing firms with information about various locations.

Just as the firm can choose among various locations for its new plant, the development agencies can choose among locations and industries at which they will direct their efforts. In order to do this, the development agency must have some basic information about location requirements and the availability of these requirements at different locations.

The purpose of this report is twofold. First, to provide location information for industrial development and promotion agencies in West Virginia to help them in attracting plants in the major wood-using industries. Second, to provide an evaluation of the relative suitability of five selected areas in West Virginia so that the development agencies can direct their major efforts at the better opportunities.

The relative suitability of the selected areas was determined through a comparison of the cost and availability of important location requirements in each area. Comparisons were made for representative plants in four major wood-using industries, although not all industries were compared in each area.

It was found necessary for analytical purposes to limit the number of industries and locations that were compared. Those used in this evaluation were chosen because they are representative; the fact that some locations and industries were not chosen for comparison does not imply that they are unsuitable. The information provided for specific locations and industries applies broadly to surrounding areas and to similar wood-using industries.

The four wood-using industries chosen for comparison are the lumber, particle-board, woodpulp, and furniture industries. These provide an interesting range of alternatives for analysis. The comparisons in each industry are made for average-size plants, which range from small in the lumber industry to fairly large in the woodpulp industry. Raw-material requirements for these plants differ in type: sawlogs for the lumber industry, pulpwood or wood residues for the woodpulp and particle-board industries, and lumber for the furniture industry. But each of four industries is representative of a basic group of wood-using industries.

The areas chosen for comparison are representative of West Virginia conditions. Each area is identified by a central city: Beckley[1] in the southeastern part of the state, Elkins in the northeastern part, Huntington in the southwestern part, Parkersburg in the west, and Richwood, which lies between Beckley and Elkins (fig. 1).

The evaluations are based on specific assumptions, indicated in the body of this report. These assumptions, which concern plant size, location of markets, and other factors important in location decisions, are realistic. However, others that might change the results of the evaluations could have been used. This point should be considered by users of this report. In a similar sense, better-than-average managers may do well at poorer-than-average locations. Thus, while this evaluation suggests that some

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[1] Because Beckley has no substantial river or stream, Hinton, a nearby city on the New River, is considered as the central location for the Beckley area in the woodpulp industry comparisons.

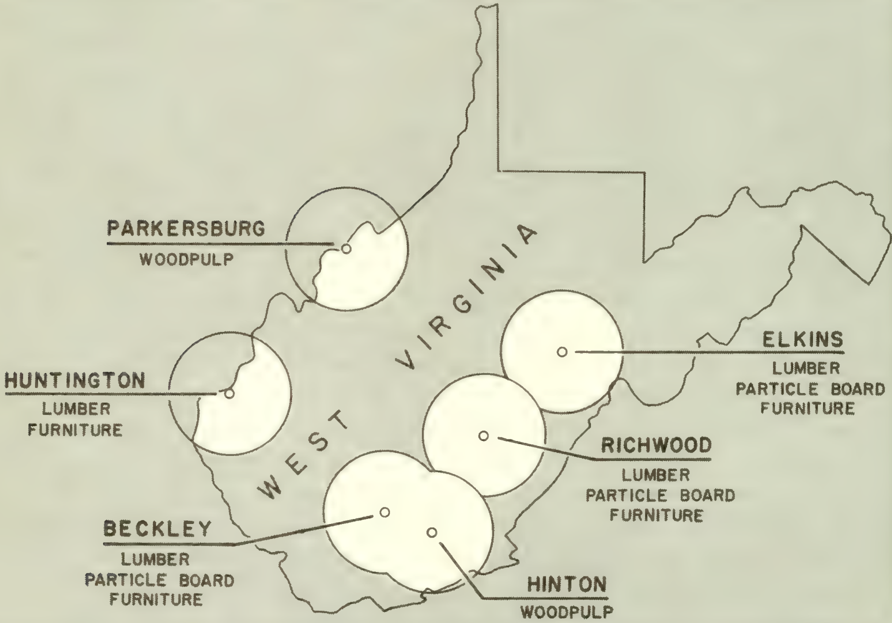

Figure 1.—The central locations studied, and the industry comparisons made at each location.

locations are better than others, it does not suggest that industrial opportunities are absolutely bad at the poorer locations.

The availability of timber resources plays an important part in the location decision for the primary wood-using industries—lumber, particle-board, and woodpulp. This report contains the latest Forest Survey statistics for the State of West Virginia. These data are based on a sampling scheme designed to get reasonably accurate data for areas smaller than the entire State. They are current as of January 1961.

What Is a Good Location?

The manager of a firm choosing a new plant location has certain criteria in mind. Perhaps the most important criterion is economic; a new plant location must be at least competitive with existing and alternative locations. Other criteria, such as a good climate and the availability of cultural, social, and recreational amenities, may also be important (Hagenstein 1962). This report is concerned primarily with the economic criteria used in choosing plant locations in the wood-using industries.

To be competitive, a plant location must have the required raw materials, labor services, and transportation services all available at a total cost that is competitive with other locations. All of these requirements must be available in quantities sufficient to sustain an industrial plant. Clearly, the exact quantities required vary with plant size. It is important for the reader to keep in mind that, while specific quantities of each requirement are necessary for a plant of a given size, the total cost of the requirements is important in judging suitability of locations. In other words, a location where one requirement is costly may be competitive if other requirements are cheap.

The quantities of the various requirements that are available place a physical limit on the expansion of industrial activity at a location. If some requirements are not available, then the location must be judged unsuitable. If substantial quantities of all the necessary requirements are present, then a sizable expansion in activity is possible.

The cost of the requirements determines the likelihood of industrial expansion. It is obvious that the locations with the necessary requirements at the lowest cost are most likely to be attractive to firms searching for new plant locations. For this reason, comparisons only of physical quantities of resources available at locations are insufficient for indicating locations at which expansion is most likely. Both the quantities of location requirements and their cost will be judged in this report.

The importance of clearly noneconomic criteria used in choosing plant locations should not be minimized. They will not be discussed in this report because of the problems involved in evaluating them. However, users of this report should consider the impact of amenities and their implication for the results of this study.

How Are Location Comparisons Made?

The firm looking for a new plant location knows what its requirements are. It has a model or set of standards that it uses in judging alternative locations. The industrial-development agency requires similar information to compare locations systematically. Of special importance to these agencies is knowledge of the particular requirements of plants in various industries.

These location requirements are much the same from one firm to the next within an industry. That is, a new plant in an industry will use about the same quantity of raw materials, labor, and transportation services per unit of output regardless of the firm that builds the plant. This means that industrial-development agencies can use a standard model for comparing the suitability of locations for an industry.

An earlier analysis of the location decision for the four wood-using industries considered in this report will serve as the model for this evaluation (Hagenstein 1964). Economic factors that affect the location decision were identified in that report for each of the industries, and the relationships among the impacts of the various factors were quantified.

It was shown that those inputs whose costs vary among locations are important in the location decision. Nine such location factors were shown to be of varying degrees of importance for the wood-using industries. Of these, certain factors are clearly more important than others. Wood, labor, and transportation of the finished product to markets are the most important factors for all four of the industries.

For wood-using industries, a number of other factors were shown to modify the impact of the economic considerations on the location decision. Wood requirements for the primary industries are of special importance. Both economic considerations and special requirements of each industry will be involved in this evaluation of selected areas in West Virginia.

The models used in evaluating the selected locations consist of a set of the required production factors for a plant of specified size in each industry (table 1). Obviously, greater quantities of inputs are required for larger plants and less for smaller plants. The plant sizes specified here were chosen as being efficient for conditions in the northern Appalachian area.

The type of plant chosen for the comparisons in each industry is well suited for using the hardwood timber resources of West Virginia. With one exception, the average plants in the models are typical of plants being built in these industries today. The exception is the woodpulp industry. Woodpulp plants built today are normally integrated with paper or paperboard plants. While the assumed semichemical woodpulp plant of the model would probably be built together with a paper or paperboard plant, the comparisons are for a woodpulp plant only.

Two types of comparisons must be made in evaluating locations. First, quantities of available production factors at a location must be compared with plant requirements to determine if plant location is feasible. Second, the costs of the required production factors must be compared to determine if the location is economically competitive. Comparisons of these two types constitute the bulk of the remainder of this report.

Are Location Requirements Available?

The major location requirements or production factors indicated in the models are available at all of the locations that have been selected for comparison.

There is some similarity in the location requirements for the four wood-using industries considered here. Each of the industries requires wood; each also requires transportation services, labor services, electric power, and industrial sites. On the other hand, the type of input in each of these broad classes may vary. For example, the lumber industry requires sawlogs, while the woodpulp industry requires pulpwood. And although there are adequate quantities of these requirements at all locations, there

Table 1.—*Models for average plants in four selected wood-using industries in West Virginia*

Item	Lumber	Particle-board	Woodpulp	Furniture
Output:				
1. Size of plant.	20,000 board feet of lumber/day (5,000,000 board feet/year).	20,000,000 square feet (¾-inch basis)/year.	200 tons/day.	Annual sales of $5,000,000.
2. Type of output.	Rough graded hardwood lumber.	Medium-quality flakeboard made largely of soft hardwood and softwood particles.	Neutral-sulfite semichemical pulp made largely from hardwoods.	Medium-quality wooden furniture (case goods).
3. Selling price/unit of product.	$90/1,000 board feet of lumber.	$130/1,000 square feet (¾-inch basis) of particle board.	$140/ton of woodpulp.	No definable units.
Operating rates:				
1. Days/year.	250 days/year.	300 days/year.	325 days/year.	275 days/year.
2. Hours/day.	8 hours/day.	22 hours/day.	24 hours/day.	8 hours/day.
Inputs:				
1. Specific.	1. Logs: 20,000 board feet/day. 2. Labor: 3 skilled, 5 semiskilled, 4 unskilled.	1. Wood: 75 cords/day. 2. Labor: 35 skilled, 35 semiskilled, 30 unskilled.	1. Pulpwood: 280 cords/day. 2. Labor: 32 skilled, 16 semiskilled, 16 unskilled.	1. Lumber: 14,500 board feet/day. 2. Labor: 75 skilled, 150 semiskilled, 75 unskilled.

	3. Transportation: highway connections required.	3. Transportation: highway connections; rail connections for noncaptive plants.	3. Transportation: rail and highway connections required.	3. Transportation: rail and highway connections required.
	4. Electricity: 750 kwh./day.	4. Electricity: 15,500 kwh./day.	4. Electricity: 55,000 kwh./day.	4. Electricity, 5,800 kwh./day.
	5. Industrial site: 20 acres.	5. Industrial site: 20 acres.	5. Industrial site: 100 acres.	5. Industrial site: 20 acres.
	6. Plant and equipment: $150,000.	6. Plant and equip- $2,500,000.	6. Plant and equipment: $10,000,000.	6. Plant and equipment: $2,500,000.
2. General.	1. Nature of hardwood timber determines markets that will be entered. Graded lumber requires good species and high-grade logs.	1. Supply of light, soft-textured hardwood or softwood usually required for plants whose product is to be sold in open market.	1. Site on a river usually required for waste disposal and water supply; quantity of water required for disposal varies depending on regulations of water commissions and nature of streamflow.	1. Labor force skilled in furniture manufacture must be available or readily developed.

are differences in both the quantity and quality of major requirements at the various locations.

The availability of wood requirements at each location deserves special attention here, since this is a limiting factor in plant location for all of the industries except the furniture industry. Water-supply and waste-disposal requirements are also limiting for the woodpulp industry. In addition, the availability of labor and transportation services varies substantially from one area to the next. The availability of each of the requirements will be discussed in turn.

To make estimates of the quantities and costs of inputs available at each location, some assumptions of a definitional nature are required. The extent of timber sheds and labor market areas must be defined, and probable markets for goods must be assigned. The necessary assumptions about wood supply, markets, and types of transportation used are indicated in table 2. Quantitative estimates of the cost and availability of the necessary inputs at each location are indicated in the appendix.

WOOD REQUIREMENTS

Species availability, timber quality, timber size, volumes per acre, and competition for the available timber are all important in comparing the availability of wood requirements at the various locations. Interpretation of data describing these factors depends on the industry being considered. Therefore, the availability of wood requirements will be considered separately for the lumber industry, for the woodpulp and particle-board industries, and for the furniture industry.

Information about the availability of timber is presented in this report for areas surrounding the central locations. The areas around each location are defined as the counties within 25 miles of the central location (25-mile area) and the counties between 25 and 50 miles of the central location (25-to-50-mile area).

For the Lumber Industry

Trees of sawtimber size (9 inches and larger in diameter at breast height for softwoods and 11 inches and larger for hardwoods) are the basic raw material for the lumber industry. But not all trees of this size are of equal value to a new sawmill. A firm hoping to compete in markets for graded hardwood lumber must be able to obtain its raw material from a timber supply of the more valuable species and of the better grades.

Table 2.—*Assumptions about wood supply and transportation used in calculating cost advantages*

Industry requirements	Industry			
	Lumber	Particle-board	Woodpulp	Furniture
Wood	1. Source: 25-mile area—75% 25-to-50-mile area—25% 2. Species: Red oak —40% White oak —25% Yellow-poplar —20% Maple —10% Beech — 5%	Source 25-mile area—100%	1. Source: 25-mile area—75% 25-to-50-mile area—25%	1. Source: 25-mile area—75% 25-to-50-mile area—25% 2. Species: Yellow-poplar —60% Maple —15% Red oak —10% White oak — 5% Black Cherry — 5% Beech — 5% 3. Grade: #1 Common.
Transportation	1. Destination: Hickory —50% Roanoke —20% Winchester —10% Charleston —20% 2. Type: 100% truck. 3. Weight: 3,400 lbs./1,000 board feet.	1. Destination: *Truck* *Rail* Hickory 10% 10% Thomasville 20% 20% Roanoke 10% 10% Winchester 10% — Charleston 10% — 2. Weight: 2,600 lbs./1,000 sq. ft. (3/4-inch).	1. Destination: *Truck* *Rail* New York — 20% Philadelphia — 20% Pittsburgh 20% — Cleveland 10% 10% Cincinnati 10% 10%	1. Destination: New York —20% Philadelphia —20% Pittsburgh —20% Cleveland —20% Cincinnati —20% 2. Type: 100% truck.

Modest increases in the cut of the better sawtimber species are feasible in West Virginia. However, the degree of competition is stronger in some of the areas than in others. Competition is particularly strong for high-value timber such as black cherry, yellow birch, and maple, and for the soft-textured hardwoods such as yellow-poplar and basswood. Competition is less strong for the oaks; and not strong at all for most other hardwoods, such as beech, hickory, and elm.

A comparison of estimated growth with estimated lumber production in each area indicates that the degree of competition for the more desirable species is strongest in the Richwood area. Competition is somewhat less strong in the Beckley and Elkins areas, although the difference between estimated growth and lumber production is small when compared to annual sawmill production (table 3).

Table 3.—*Estimated sawtimber growth and lumber production for selected species groups, by location*[1]

Item	Oaks	Yellow-poplar, basswood, cucumber	Maples, cherry, yellow birch	Other[2] hardwoods	Softwoods
Beckley:					
Growth, M board feet	114	50	35	69	11
Cut, M board feet	54	41	22	22	16
Ratio	2.1	1.2	1.6	3.1	0.7
Elkins:					
Growth, M board feet	83	27	31	50	17
Cut, M board feet	36	23	15	15	6
Ratio	2.3	1.2	2.1	3.3	2.8
Huntington:					
Growth, M board feet	26	4	4	14	2
Cut, M board feet	7	6	1	3	1
Ratio	3.7	0.7	4.0	4.7	2.0
Richwood:					
Growth, M board feet	83	32	31	51	15
Cut, M board feet	47	36	28	18	15
Ratio	1.8	0.9	1.1	2.8	1.0

[1] Annual sawtimber growth estimated as 2½ percent of 1961 sawtimber inventory. Lumber production estimates from Frank 1963. Growth and cut estimates are for counties within 50-mile areas surrounding the selected locations.

[2] Includes hickory, beech, ash, and black walnut.

Table 4.—*Selected forest resource statistics, by location, 1961*[1]

Item	Beckley		Elkins		Huntington		Richwood	
	25-mile area	25-to-50-mile area	25-mile area	25-to-50-mile area	25-mile area	25-to-50-mile area	25-mile area	25-to-50-mile area
				Percent				
Area forested	81	84	76	69	71	81	80	77
				Thousand acres				
Area of commercial forest land	1,324	2,859	1,042	2,113	558	407	1,630	1,438
Area in hardwood sawtimber stands	658	1,449	532	1,034	246	175	832	731
Area in hardwood sawtimber stands of more than 5,000 board feet/acre	218	484	172	334	79	56	282	237
				Million board feet				
Total hardwood sawtimber volume	3,360	7,349	2,549	5,081	1,122	813	4,185	3,676
Sawtimber volume in—								
Oaks	1,449	3,120	1,096	2,240	620	437	1,711	1,604
Yellow poplar, basswood	574	1,263	338	656	97	72	611	537
Maple, cherry, yellow birch, walnut, ash	423	969	534	1,035	129	92	798	632
Hardwood sawtimber volume in grade 1 and grade 2 logs	1,078	2,348	703	1,406	349	252	1,261	1,070
Hardwood sawtimber volume in diameter classes 16 inches and larger	2,167	4,742	1,490	2,962	660	479	2,568	2,233

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[1] Statistics are for counties within 25 miles and between 25 and 50 miles of central locations. Specific areas are shown in appendix.

In absolute terms, the Beckley area has greater volumes of timber in all species groups than any of the other areas. The Huntington area has by far the smallest total volume of timber; it is considerably smaller than any of the other three areas because it includes only the West Virginia portions of a 50-mile ring around the city. Data for forest resources in the Ohio and Kentucky parts of the Huntington area were not included in this report.

All of the areas have substantial volumes of timber in sawtimber stands of more than 5,000 board feet per acre, in grade 1 and grade 2 logs, and in timber 16 inches and over in diameter at breast height (table 4). Differences in average timber quality among the areas do not appear to be very important, as shown in the following tabulation of total hardwood sawtimber volume by log grades:

Area[2]	*Grade 1 (percent)*	*Grade 2 (percent)*	*Grade 3 (percent)*	*Tie-and-timber (percent)*
Beckley	10.8	21.2	42.7	25.3
Elkins	10.1	17.5	47.0	25.4
Huntington	10.8	20.3	39.5	29.4
Richwood	10.4	19.2	45.0	25.4

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[2] For 25-mile area, plus the 25-to-50-mile area.

It is not possible here to determine the extent to which the sawtimber cut should be changed. Substantial sawtimber volumes of the oak and the other hardwood group (hickory, beech, and minor species) could be removed in all areas. On the other hand, it appears that only modest increases in the cut of the better species could be sustained in the long run in the Beckley and Elkins areas. In the Huntington and Richwood areas, increases in the cut of the better species might result in unfavorable growth-drain ratios.

For the Woodpulp and Particle-Board Industries

The woodpulp and particle-board industries use pulpwood and sawmill residues for their primary wood requirements. Semichemical woodpulp mills can use practically all commercial hardwood species. Particle-board plants, on the other hand, are generally restricted to using the soft hardwoods (basswood, yellow-poplar, and the like) or softwoods.

At present only small quantities of pulpwood are being cut

Table 5.—*Volume of growing stock, by location and major species group, 1961*[1]

(In thousands of standard cords)[2]

Location[3]	Softwoods	Oaks	Yellow-poplar, basswood	Maple, beech, yellow birch	Other hardwoods	Total
Beckley:						
25-mile area	611	6,126	2,715	2,671	4,134	16,257
25-to-50-mile area	1,410	13,795	5,879	6,299	8,992	36,375
Total	2,021	19,921	8,594	8,970	13,126	52,632
Elkins:						
25-mile area	1,000	5,094	1,498	3,309	3,135	14,036
25-to-50-mile area	1,911	10,519	3,001	6,357	6,230	28,018
Total	2,911	15,613	4,499	9,666	9,365	42,054
Huntington:						
25-mile area	279	2,570	465	625	1,525	5,464
25-to-50-mile area	206	1,794	357	508	1,154	4,019
Total	485	4,364	822	1,133	2,679	9,483
Parkersburg:						
25-mile area:	316	3,394	591	741	1,879	6,921
25-to-50-mile area	355	3,588	644	856	2,031	7,474
Total	671	6,981	1,235	1,597	3,910	14,395
Richwood:						
25-mile area:	1,490	8,069	2,871	5,114	5,425	22,969
25-to-50-mile area	1,045	7,058	2,459	3,891	4,356	18,809
Total	2,535	15,127	5,330	9,005	9,781	41,778

[1] Growing stock includes all merchantable trees of commercial species, 5.0 inches and larger in diameter at breast height.

[2] Estimated by using factor of 80 cubic feet of wood inside bark per standard cord.

[3] Volume estimates are for counties within 25 miles and between 25 and 50 miles of central locations. Specific areas are shown in appendix.

Table 6.—*Estimated annual growth of growing stock, by location and species group*[1]

(In thousands of cords)

Location[2]	Softwoods	Oaks	Yellow-poplar, basswood	Maple, beech, yellow birch	Other hardwoods	Total
Beckley	98	618	382	202	476	1,776
Elkins	141	484	200	218	337	1,380
Huntington	24	136	36	25	97	318
Parkersburg	33	216	55	36	141	481
Richwood	123	469	237	203	352	1,384

[1] Growth estimates were obtained by applying statewide growth percents for indicated species groups to inventory of growing stock at each location.

[2] For 25-mile plus 25-to-50-mile areas.

in West Virginia and shipped to woodpulp mills in the surrounding states. Some hardwood sawmill residues are being used, but substantial quantities are still available (Frank 1963). A large expansion in either the woodpulp or particle-board industry could be sustained by pulpwood produced in West Virginia. The volume of the growing stock (merchantable trees over 5 inches in diameter at breast height) is greatest in the Beckley, Elkins, and Richwood areas, but is also substantial in the Parkersburg and Huntington areas (table 5).

There is now considerable drain on these volumes of standing timber. A good part of the larger trees goes into lumber production, and in some areas a part goes into pulpwood and minor products. This still leaves substantial volumes of timber in the smaller size classes that could be removed without lowering the growth potential of the forest.

A woodpulp plant of the size indicated in the location model has annual pulpwood requirements of just over 90,000 cords. The particle-board plant requires 22,500 cords. A comparison of these figures with estimated total annual growth of growing stock shows that growth in any of the areas is sufficient to sustain one or more woodpulp mills or particle-board plants, even if half the total growth were used for other purposes (table 6).

The differences in growth among species groups are important—especially for the particle-board industry. The annual growth of soft hardwoods and softwoods is considerably less than that of the hard hardwood species groups. However, the growth figures indicate sufficient volumes of the soft species to sustain substantial particle-board production. Among the areas compared as particle-board plant locations (Beckley, Elkins, Richwood), the annual growth of both soft hardwoods and softwoods is roughly equal.

The availability of sawmill residues is also of some importance to these industries. The volume of chippable soft hardwood residues produced in the Beckley area is just sufficient to sustain a particle-board plant of the indicated size. In the Elkins and Richwood areas, there are enough of these residues to cover half of the wood requirements of such a plant (Frank 1963).

The quantity of available sawmill residues is greater in the Beckley area than in the Parkersburg area, although neither Beckley nor Parkersburg has enough available sawmill residues to support a woodpulp mill. The residues that are available could serve as an important source of perhaps one-fourth of the wood requirements of a woodpulp mill.

Competition for sawmill residues at present is increasing. More are being utilized now than at any time in past years.

For the Furniture Industry

Lumber and dimension stock used in furniture manufacture are commonly shipped long distances to furniture plants. Thus hardwood lumber is more or less ubiquitously available. However, since shipping costs are an important component of the total cost of lumber, total furniture-production costs can be reduced somewhat by locating plants close to supplies of the required lumber species and grades.

Sufficient lumber is produced in all of the selected areas to supply all of the requirements of several good-sized furniture plants (Frank 1963). More lumber is produced in the Beckley and Richwood areas than in the Elkins and Huntington areas, as shown in the following tabulation (from Frank 1963) of lumber production in 1960 (in millions of board feet):

Location[3]	*Oaks*	*Poplar, basswood, cucumber*	*Maple, cherry, birch*	*Other hardwoods*
Beckley	54	41	22	22
Elkins	36	23	15	15
Huntington[4]	18	16	3	7
Richwood	47	36	28	18

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[3] For counties within 50 miles of central locations.

[4] Includes lumber production in selected counties of Ohio and Kentucky within 50 miles of Huntington.

The largest volumes of desirable furniture lumber are produced in the Beckley and Richwood areas, but the other two areas also produce sizable volumes of maple, cherry, birch, and yellow-poplar. Other factors that affect the desirability of the lumber production in these areas were discussed in an earlier report (Frank 1963). Based on this information, the conclusion is that availability of lumber is satisfactory in all four areas.

LABOR REQUIREMENTS

It is difficult to specify the extent of the labor force that might be available to a new plant in an area. Much depends on current employment levels, relative wage rates, population density, and commuting patterns. One usable measure of the potentially available labor force is the number of unemployed workers in an area. This is the measure used in this report.

All of the selected areas have a sufficient number of unemployed workers to meet the requirements of one or more new plants in any of the selected industries. Huntington and Parkersburg have the largest total labor forces of the selected areas; but Beckley has a substantially larger unemployed work force than any of the other four, a reflection in part of the depressed conditions in coal-mining areas. Elkins has the smallest labor force. But even Elkins has enough unemployed workers to staff a good-sized plant in the furniture industry, which, of the four industries, requires the most labor per unit of output.

Labor is not a homogeneous factor, so not all of the labor force is equally well suited to employment in the wood-using industries. Skill classes, age, and education are all of some importance in defining labor-force quality. The three standard skill classes used in most labór-market reports are broad, and they include many particular skills that are not transferable among industries. On the other hand, they do indicate an ability to acquire skills. Labor in the upper skill classes is probably more readily trained for new jobs than labor in the lower skill classes. Age and education are also related to the ability to acquire new skills and handle new jobs.

Average skill, age, and education of unemployed workers vary somewhat among the five areas. Average skill levels are highest in the Elkins area and lowest in the Beckley area. Average education levels are highest in Parkersburg and Huntington and lowest in Beckley and Richwood. The average age of unemployed workers is somewhat greater in Elkins than in the other areas.

On the other hand, the total number of unemployed workers with a 12th grade education or better and in the upper skill class is greatest in absolute terms in the Beckley area. For the firm locating a new plant in West Virginia, these qualitative differences in the labor force are of some importance. With the possible exception of labor for the lumber industry, some form of training—probably on-the-job training—would be necessary at all locations.

Labor-training programs would be most important for the furniture industry. Some four-fifths of the employment in wood furniture plants in West Virginia is in the Huntington area (U. S. Bureau of the Census 1961); there is also some employment in furniture manufacture in the Elkins area. These areas provide a base on which to build and develop further furniture-making skills. Therefore training costs would probably be lowest at Huntington and highest at Richwood and Beckley.

TRANSPORTATION REQUIREMENTS

Both rail and truck transportation services are available at all locations. The relative availability of these services depends on the type of freight lines and highways serving the selected locations.

Three major rail systems cross West Virginia in an east-west direction (fig. 2). The Baltimore and Ohio main line crosses the northern part of the State, passing through Parkersburg, with connections to Elkins, Richwood, Charleston, and Huntington. The Chesapeake and Ohio main line passes through Huntington and Charleston and has a branch line to Beckley (the main line passes through Hinton in the Beckley area). The Norfolk and Western runs through southern West Virginia with connections to Beckley and Huntington. In addition, Elkins is on the main line of the Western Maryland, which connects parts of northeastern West Virginia with the Baltimore and Ohio main lines.

The present status and plans for the public highway system are important in evaluating the suitability of truck transportation. The present highway system in West Virginia is poor. However, it will be improved by the new national system of interstate and defense highways, now under construction (fig. 2).

Two important links of the interstate system pass through the portions of West Virginia being considered here. The first is a north-south highway from Cleveland, Ohio, through Parkersburg, Charleston, and Beckley to points in the industrial area of central-western North Carolina. About one-third of the Parkers-

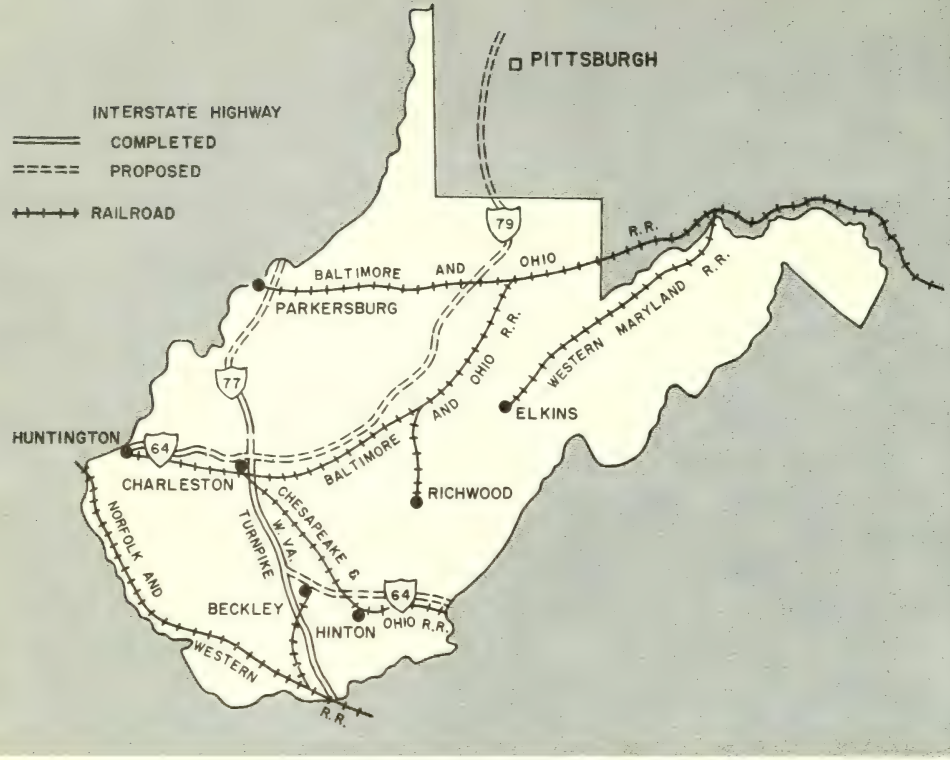

Figure 2.—The interstate highway and major railroad connections serving the selected locations in West Virginia.

burg-Charleston link is complete. The West Virginia Turnpike, which is to be a part of the interstate system, is complete from Charleston through Beckley to the southern edge of West Virginia. No work has been done on the connecting portions in Ohio and Virginia.

The second link is an east-west highway from Richmond, Virginia, through Charleston and Huntington to Louisville, Kentucky. A major part of the Huntington-Charleston section has been completed. However, the remainder of the West Virginia portion and the connecting sections in Virginia and Kentucky have not yet been started. A third link in the interstate system will connect the Charleston area with Pittsburgh, but little progress has been made on this link.

In sum, Beckley, Huntington, and Parkersburg are favorably located on east-west main line railroads; Elkins and Richwood are connected to these main lines. But none of these locations has good north-south rail connections. Huntington and Parkersburg have good highway connections with markets in the Midwest, but poor connections with markets in the East and South. The other three locations have poor highway connections in all directions. When completed, the interstate system will help Beckley, Huntington, and Parkersburg considerably, but it will be of less help to Elkins and Richwood.

WATER-SUPPLY AND WASTE-DISPOSAL REQUIREMENTS

Water-supply and waste-disposal requirements can be critical in their impact on the location decision for the woodpulp industry. Water requirements for use in the production process are generally less critical than requirements for waste disposal.

Records of waterflow for major sources of surface water in the Beckley area and at Parkersburg indicate that any one of the rivers at these locations has sufficient low-water flow for use in production, with the possible exception of the Little Kanawha River at Parkersburg. The quality of the water in the Beckley area and in the Little Kanawha is such that only simple filtering and settling would be required prior to use. A somewhat more costly and complex system might be required if Ohio River water were to be used at Parkersburg.

The effluent from a 200-ton-per-day semichemical pulpmill totals about 7,000,000 gallons per day, with about 3 to 4 tons of suspended solids and a BOD (biochemical oxygen demand) of 40,000 to 80,000 pounds per day (California State Water Pollution Control Board 1957). The amount of water required to dilute this effluent and maintain stream conditions within qualitative limits required by pollution-control agencies depends on (1) the requirements that must be met and (2) the nature of the stream into which the effluent is dumped.

The West Virginia Water Resources Commission does not have its requirements for woodpulp-effluent control fully specified. Since there are no pulpmills in the State, the Commission has never had to deal directly with the problem of pulpmill effluent. However, the Commission has stated that a pulpmill would have to remove roughly 90 percent of the suspended solids prior to discharge. Furthermore, a minimum of 3 to 5 parts per million of available oxygen would have to be maintained in the stream below the point of discharge.

Without waste treatment, a 200-ton-per-day semichemical mill would require a waterflow of about 1,360 cubic feet per second (cfs.) to maintain the oxygen level at 5 parts per million at 75°F. in the New River, Greenbrier River, or Little Kanawha River. For other types of pulpmills, these waterflow requirements would be lower: about 340 cfs. for unbleached cold soda, 420 cfs. for bleached cold soda, and 340 cfs. for bleached sulfate. If the requirements for a semichemical mill are compared with the minimum flows in any of the three rivers, it is apparent that some form of waste treatment would be required, and that more facilities would be required for the Greenbrier and Little Kanawha Rivers than for the New River. Settling basins to remove solids would be required at all locations.

Since minimum flows in the Ohio River are considerably greater than those in the other streams being considered, location on the Ohio River appears to be more feasible from the waste disposal requirement aspect than a location on any of the other rivers. Treatment facilities for wastes would be required, but it is likely that greater leeway would be afforded at Parkersburg than in the Beckley area.

Unfortunately, from the point of view of the firm, there is considerable uncertainty surrounding waste-disposal requirements in most areas of the United States. It is difficult to specify facilities required to meet a specific set of standards because of variation in streamflows over time; and lack of engineering data presents another difficulty. As a result, regulatory commissions commonly are unwilling to guarantee firms that a given investment in disposal facilities will be sufficient to meet the commission's requirements.

Faced with such uncertainty, the firm is forced to choose among three unsatisfactory alternatives. It can look for other locations where the uncertainty is less but where other costs may be higher. It can provide disposal facilities with costly safety margins. Or it can provide minimum disposal facilities and face the prospect of being forced to make costly additions in the future to protect its investment in the remainder of the plant. Solution of the problem would require careful study of effluent characteristics for mills of different types and development of specific treatment facilities for specified conditions.

What Do the Cost Comparisons Show?

The relative economic suitability of the selected locations was established by comparing costs likely to be incurred at each location for the important production factors. The comparisons make it possible:

- To identify the better locations for each industry.
- To identify the production factors that are most favorable and most unfavorable at each location.

To do this, the selected locations were viewed much as a wood-using firm might view them when selecting a new plant location. The firm evaluates the overall impact of those requirements whose cost varies among locations. The costs of six of these requirements for each industry were evaluated here:

- Wood costs.
- Labor costs.
- Cost of transporting finished product to market.
- Local property taxes.
- Electric power costs.
- Cost of industrial sites.

The cost comparisons were made for each industry in terms of daily and annual cost advantages that accrue to each location as compared with the other locations. Daily cost advantages for each location were measured relative to the highest cost location for each location requirement.

The type of quantitative cost comparison used here was chosen because it is well suited to determining the impact of the various location requirements at various locations. Although the cost comparisons may appear unfamiliar and cumbersome, they can be duplicated easily for other locations if cost information is available. The daily cost advantage for a requirement at a location is simply the per-unit cost advantage times the number of units required per day.

A summary of the daily cost advantages, by locations and industries, was made in terms of total annual cost advantages; and these were compared with estimated total annual sales for plants in each industry. This comparison makes it possible to judge the impact of daily cost advantages on the overall performance of the firm. Annual sales—rather than total investment

—were used because of the consistency this figure offers among industries of the type being examined here.

Some assumptions about the raw-material supply and transportation of the finished product to markets were required to establish specific cost levels for these production factors. The assumptions concern: (1) the quantity of raw material obtained from the 25-mile and 50-mile procurement areas around each

Table 7.—*Cost advantages for the lumber industry, by location and factor*[1]

Factor	Beckley	Elkins	Huntington	Richwood
Logs	$21.00	$69.00	—	$47.75
Labor	4.80	8.40	—	10.40
Transportation	43.60	6.80	—	23.20
Local taxes	—	2.93	—	2.21
Electricity	4.50	—	$4.50	—
Industrial site	1.20	1.20	—	2.40
Total	$76.10	$88.33	$4.50	$85.96
Daily advantage[2]	$71.60	$83.83	—	$81.46
Annual advantage[3]	$17,900.00	$20,957.50	—	$20,365.00

[1] Daily cost advantages for each factor are expressed as daily saving relative to the highest cost location for that factor.

[2] Advantage is expressed as total cost saving relative to the overall highest cost location.

[3] Annual cost advantage assumes 250 working days/year.

Table 8.—*Cost advantages for the particle-board industry, by location and factor*[1]

Factor	Beckley	Elkins	Richwood
Wood	—	$108.75	$45.00
Labor	—	26.00	40.00
Transportation	$208.97	48.56	—
Local taxes	—	44.33	33.42
Electricity	—	17.05	17.05
Industrial site	—	—	1.00
Total	$208.97	$244.69	$136.47
Daily advantage[2]	$72.50	$108.22	—
Annual advantage[3]	$21,750.00	$32,466.00	—

[1] Daily cost advantages for each factor are expressed as daily saving relative to the highest cost location for that factor.

[2] Advantage is expressed as total daily cost saving relative to the overall highest cost location.

[3] Annual cost advantage assumes 300 working days/year.

location; (2) species and grades of material used in the manufacturing process; (3) markets for products; and (4) the type of transportation used to ship products to markets.

Daily cost advantages were calculated, by industry, for each of the six location requirements (tables 7 to 10). Cost advantages

Table 9.—*Cost advantages for the woodpulp industry, by location and factors*[1]

Factor	Beckley	Parkersburg
Wood	$308.00	—
Labor	—	—
Transportation	—	$584.00
Local taxes	142.77	—
Electricity	—	110.00
Industrial site	18.45	—
Total	$469.22	$694.00
Daily advantage[2]	—	$224.78
Annual advantage[3]	—	$73,053.50

[1] Daily cost advantages for each factor are expressed as daily saving relative to the highest cost location for that factor.

[2] Advantage is expressed as total daily cost saving relative to the overall highest cost location.

[3] Annual cost advantage assumes 325 working days/year.

Table 10.—*Cost advantages for the furniture industry, by location and factor*[1]

Factor	Beckley	Elkins	Huntington	Richwood
Wood[2]	$179.98	$ 88.45	$128.69	—
Labor	—	186.00	372.00	—
Transportation	—	133.82	100.07	$16.29
Local taxes	—	44.33	24.49	33.42
Electricity	29.00	—	29.00	—
Industrial site	1.10	1.10	—	2.20
Total	$210.08	$453.70	$654.25	$51.91
Daily advantage[3]	$158.17	$401.79	$602.34	—
Annual advantage[4]	$43,497.00	$110,492.00	$165,644.00	—

[1] Daily cost advantages for each factor are expressed as daily saving relative to the highest cost location for that factor.

[2] Differences in wood costs among locations were estimated from unpublished data, Northeastern Forest Experiment Station, Upper Darby, Pa.

[3] Advantage is expressed as total daily cost saving relative to the overall highest cost location.

[4] Annual cost advantage assumes 275 working days/year.

for the various requirements were then summed, and the totals were compared with the location that had the lowest total cost advantage.

For any single location requirement, the magnitude of the economic advantage accruing to a location is measured directly by the cost advantage. This is also true for comparisons among location requirements. Thus, the comparisons can be used: (1) to indicate locations that have advantages in particular factors and, conversely, those that have disadvantages in particular factors; and (2) to indicate locations that are most advantageous for each industry.

The relative importance of the six production factors is brought out clearly in the cost comparisons. Differences in the cost of wood, labor, and transportation weigh most heavily in nearly all comparisons; but the relative importance of the factors differs among the industries. As investment in plant and equipment increases among the industries, local taxes increase in importance. Power costs also assume greater importance for the industries, such as woodpulp, that have large power requirements.

The impact of these cost advantages can be judged from the comparisons of total annual cost advantage as a percent of total annual sales (table 11). The percentage figures indicated for each industry are relative to the highest cost location; they indicate the part of annual sales available for covering costs and for profit above that available at the highest cost location.

The differences shown for the lumber and furniture industries are substantial; for both, the cost advantages of the better locations over the poorest are in the neighborhood of annual profits as a percent of sales being made by average firms in these industries. The differences for the particle-board industry are only moderate, while those for the woodpulp industry are somewhat less. Thus, these cost comparisons give a strong basis for selecting

Table 11.—***Annual cost advantages as a percent of total annual sales, by location and industry***[1]

Industry	Beckley	Elkins	Huntington	Parkersburg	Richwood
Lumber	3.98	4.66	—	—	4.53
Particle-board	.84	1.25	—	—	—
Woodpulp	—	—	—	0.80	—
Furniture	.87	2.21	3.31	—	—

[1] Estimated annual sales for the average plants are: lumber, $450,000; particle-board, $2,600,000; woodpulp, $9,100,000; furniture, $5,000,000

locations for the lumber and furniture industries, a less strong basis for the particle-board industry, and a fairly weak basis for the woodpulp industry.

The cost comparisons indicate the following:

- *Lumber.* — Elkins, Richwood, and Beckley all have substantial cost advantages over Huntington. Elkins and Richwood have slight cost advantages over Beckley.
- *Particle-board.* — Elkins and Beckley have modest cost advantages over Richwood.
- *Woodpulp.* — Parkersburg has a modest cost advantage over Beckley.
- *Furniture.* — Huntington has substantial cost advantages over Beckley and Richwood and modest cost advantages over Elkins. Elkins has a substantial cost advantage over Richwood and a modest cost advantage over Beckley.

The cost comparisons have pointed up the magnitude of differences in profits that can be obtained through careful location decisions. The overall impact of these comparisons must now be considered in light of timber-resource characteristics and other important requirements.

Which Opportunities Are Most Favorable?

The comparisons indicate that at least one of the selected locations is better than the others for each industry. They also indicate that each location is better than others for at least one industry.

The fact that some locations are considered better than others neither means that the best locations are ideal in all respects, nor that the poorest locations are wholly adverse. West Virginia's wood-using industries, with the exception of lumber, are relatively underdeveloped; this shows that there probably are some obstacles to plant location in most areas. These obstacles are likely to be less critical in the case of the best locations. It is also likely that less effort would be required to make the best locations truly attractive.

The results of the overall comparisons of costs and availability of wood, labor, and other requirements at the selected locations indicate locational advantages among locations ranging from substantial to slight (table 12).

For the lumber industry, the importance of timber availability was sufficient to modify somewhat the results of the cost comparisons. Advantages of water-supply and waste-disposal requirements strengthen the results of cost comparisons for the woodpulp industry. The availability of labor skilled in furniture manufacture strengthens the results of cost comparisons for the furniture industry.

Table 12.—*Comparison of locational advantages by industry, for selected locations in West Virginia*

Location	Advantage over poorest location	Major cost advantages	Remarks
		LUMBER INDUSTRY	
Elkins	Substantial	Wood costs.	Best timber resource.
Beckley	Modest	Transportation costs for products.	Moderately good timber resources.
Richwood	Modest	Wood and transportation costs for products.	Strong competition for better species of timber.
Huntington	—	—	—
		PARTICLE-BOARD INDUSTRY	
Elkins	Modest	Wood costs.	—
Beckley	Modest	Transportation costs for products.	Best rail and truck connections to important markets.
Richwood	—	—	—
		WOODPULP INDUSTRY	
Parkersburg	Modest	Transportation costs for products.	Water supply and waste disposal requirements favorable.
Beckley	—	Wood costs.	—
		FURNITURE INDUSTRY	
Huntington	Substantial	Labor, wood, and transportation costs.	Best labor for furniture manufacture.
Elkins	Substantial	Transportation and labor costs.	Fairly good labor for furniture manufacture.
Beckley	Slight	Wood costs.	—
Richwood	—	—	—

No comparisons were made with locations outside West Virginia. In addition, no analyses of specific markets were made; the relative advantages of the selected locations were determined independent of purely market considerations. This is the view of industrial location that might well be taken by industrial-development groups within the State. This limited viewpoint would still enable development groups to concentrate their efforts on the better locations within the State.

However, these groups might also be interested in the prospects for expanded production by the wood-using industries in West Virginia. This added information would enable them to concentrate efforts on industries with better growth prospects in West Virginia.

How Good Are Expansion Prospects?

Statewide industrial development in the wood-using industries depends on two factors. First, it depends on the extent and character of national growth in the wood-using industries themselves. Second, it depends on the State's competitive advantages and disadvantages with respect to other areas for these industries (Perloff *et al.* 1960). Both factors are important for an evaluation of prospects for expansion of the wood-using industries in West Virginia.

United States production of forests products has been changing at varying rates for the four industries considered here. Annual hardwood lumber production has been decreasing slowly since World War II. The production of woodpulp and furniture have been increasing at about the same rate of growth as the whole economy. Particle-board production has been increasing at a very rapid rate, although total production in the industry is still at a low level compared with that of the other three industries.

In the near future—say the next 5 to 10 years—it is likely that new plants will be built in all of the industries. In the three industries in which production is increasing, most of these plants will be built to meet the increased demands for production. In the hardwood lumber industry, new plants will be built mostly to obtain lower costs for a relatively constant level of production.

For West Virginia, this means that prospects for new plants in the woodpulp, particle-board, and furniture industries are good if the State gets its share of the national growth in these industries. For new plants in the hardwood lumber industry, prospects based solely on national growth of the industry are not likely at the present time.

No direct comparisons were made in this report of the competitive position of West Virginia relative to other states for the four selected industries. But the present status of the wood-using industries in the State does throw some light on the competitive position of West Virginia.

Of the four industries, only the hardwood lumber industry, which ranked tenth in production in the United States in 1962 (U. S. Bureau of the Census 1963), has achieved any level of importance in the State. It appears that West Virginia is likely to maintain its position as an important producer of hardwood lumber and sawmill products. It has a good timber resource base and is reasonably close to many important hardwood lumber markets.

The development of the woodpulp and particle-board industries in West Virginia has been restricted because the bulk of the State's timber resource is in hardwood timber. Neither industry has obtained a major part of its raw material from hardwoods. However, a lack of softwoods is becoming less of an obstacle to the location of these industries. It seems likely that West Virginia will get an increased share of the plants that can utilize hardwoods in these industries. The pulpwood resources of the State have hardly been tapped and the State is reasonably close to important markets. Prospects for woodpulp plants are somewhat better than for particle-board because the woodpulp industry is larger and can effectively use a greater variety of timber species.

Prospects for the furniture industry seem somewhat less good than those for the other three industries. Because of the importance of labor skills and exchange of information about styles, centers of furniture manufacturing tend to be self-perpetuating (Hagenstein 1964). The wooden furniture industry tends toward greater concentration in certain areas, and this tendency may work to West Virginia's disadvantage. On the other hand, it seems likely that West Virginia will increase in importance as a manufacturer of furniture parts and dimension stock.

Summary

This evaluation of five selected areas in West Virginia shows that all have sufficient quantities of the necessary production factors for new plants in four wood-using industries. The comparisons among the areas indicate that some areas are better for the selected wood-using industries than others and that each area has at least moderate advantages for one industry over the other areas. It was shown that:

- Elkins, Richwood, and Beckley have advantages for the lumber industry.
- Elkins and Beckley have advantages for the particle-board industry.
- Parkersburg has advantages for the woodpulp industry.
- Huntington and Elkins have advantages for the furniture industry.

In addition to the comparisons among locations in West Virginia, prospects for increased levels of wood use in West Virginia in the near future were considered. It appears that prospects for new lumber, dimension stock, furniture parts, and woodpulp mills are somewhat better than for new furniture and particle-board plants. These considerations are based in part on the expected increases in production nationwide in these industries and in part on the comparative advantages of West Virginia for these industries.

The methods used in this report for comparing costs in each industry could be extended to other areas in the eastern United States. The comparisons show that both costs for important location requirements and the availability of timber resources, labor, water, and transportation services are important in evaluating plant locations for the wood-using industries.

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Appendix

I

AVAILABILITY AND COST OF WOOD INPUTS

(Tables 13 to 52)

The information in this appendix about the availability of timber supplies in the five selected areas of West Virginia was developed in the forest survey conducted by the Northeastern Forest Experiment Station in West Virginia in 1961. The results of this survey are based on a sampling scheme designed to give greater accuracy than that normally required by Forest Survey. In other words, reasonable confidence can be placed in the accuracy of the data presented in these tables.

The information here is organized to bear on plant-location decisions in the four selected wood-using industries. Because the availability of wood supplies to a plant depends in large part on the distance between the timber and plant, the timber-supply information is presented for counties falling roughly within a 25-mile radius and between a 25-mile and 50-mile radius of the central location.

The areas used in presenting the forest-inventory data are defined by the counties in the 25-to-50-mile areas. They are as follows:

	25-mile area	*25-to-50-mile area*	
Beckley:	Fayette Raleigh Wyoming Mercer Summers	McDowell Logan Kanawha Nicholas Monroe	Mingo Boone Clay Greenbrier
Elkins:	Barbour Randolph Tucker Upshur	Preston Harrison Braxton Pocahontas Grant	Taylor Lewis Webster Pendleton
Huntington:	Mason Cabell Wayne	Lincoln	Putnam
Parkersburg:	Jackson Pleasants Ritchie Wirt Wood	Calhoun Gilmer Tyler	Doddridge Roane
Richwood:	Greenbrier Nicholas Webster Pocahontas	Fayette Braxton Randolph	Clay Upshur

The forest-resource data for these areas follow in tables 13 to 52. Forest-survey data for the State as a whole and for individual counties are available in *The Timber Resources of West Virginia,* recently published by the Northeastern Forest Experiment Station (U. S. Forest Resource Bulletin NE-2, 123 pp., 1964).

In addition to differences in the kind of timber that is available in the selected areas, there are differences in logging costs for both sawlogs and pulpwood. These differences are based primarily on differences in topography, average distance from timber stands to the central location, and timber volumes. Estimates of logging-cost differentials among the selected areas are shown in table 53. For the 25-to-50-mile areas these cost differences include estimated additional hauling costs to the central location of $2.50 per 1,000 board feet for sawlogs and $1.00 per standard cord for pulpwood.

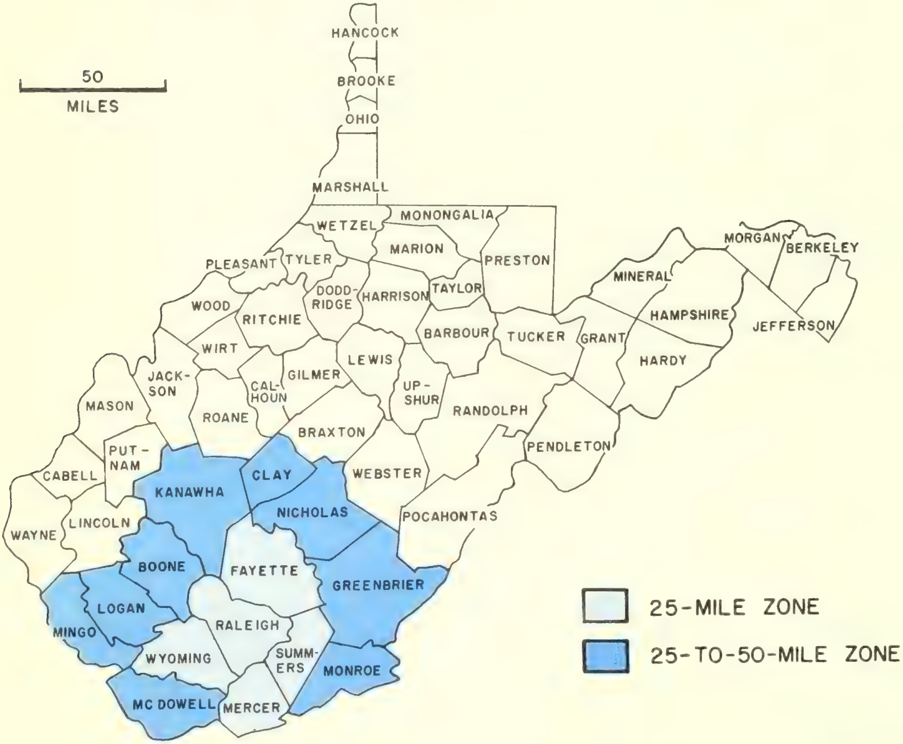


Figure 3.—The Beckley area of West Virginia, showing the counties in the two zones considered.

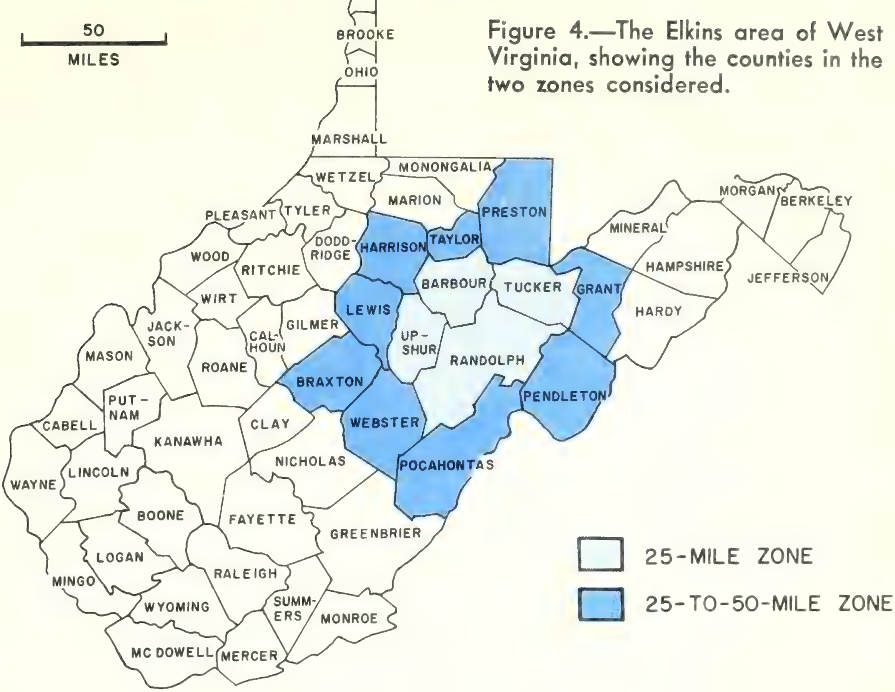


Figure 4.—The Elkins area of West Virginia, showing the counties in the two zones considered.

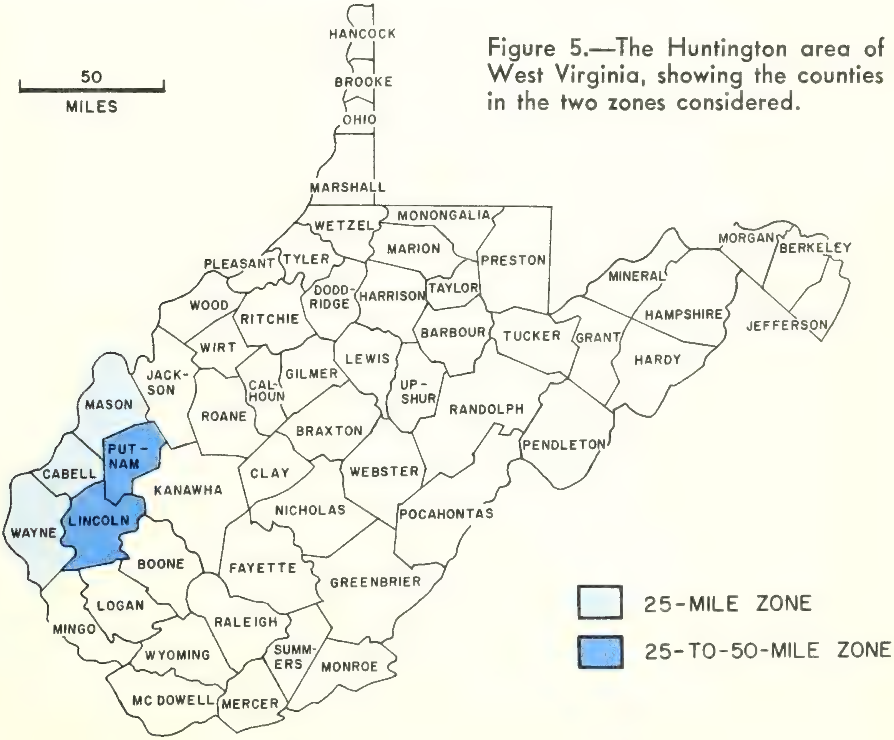


Figure 5.—The Huntington area of West Virginia, showing the counties in the two zones considered.

Figure 6.—The Parkersburg area of West Virginia, showing the counties in the two zones considered.

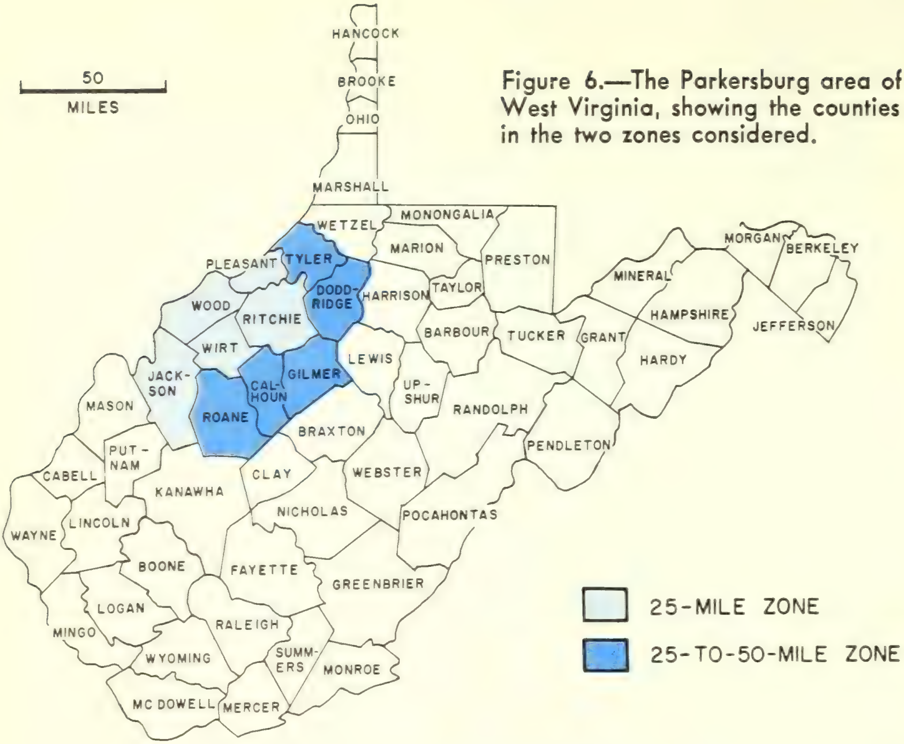
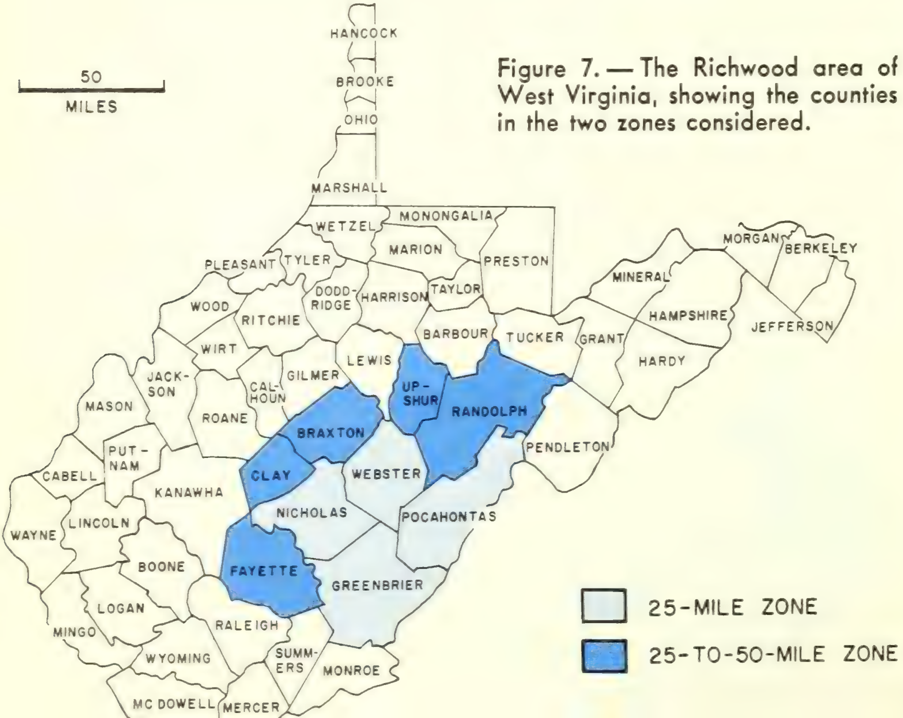


Figure 7. — The Richwood area of West Virginia, showing the counties in the two zones considered.



II

AVAILABILITY AND COSTS OF NONWOOD INPUTS

(Tables 53 to 65)

The tables in this appendix contain information about the availability and cost of nonwood inputs for the selected locations in West Virginia. This information was obtained from a number of sources; all had to be evaluated and combined into consistent form. This required certain assumptions for some inputs.

The assumption made concerning destinations for products of the four industries are evident from appendix tables 54 to 57; for each industry the indicated destinations seemed most probable although others might be used. The labor force estimates were made using an assumed maximum one-way commuting distance of 20 miles; data were collected for counties falling almost entirely within a 20-mile radius of the central location.

Average hourly wage rates do not include fringe benefits paid by employers because these are difficult to estimate and do not appear to vary importantly among locations in West Virginia. Electricity rates for the four industries were estimated by using power-rate schedules and estimates of power required for plants in each industry.

All estimates made in this appendix have been checked through consultation with sources and with agency personnel in West Virginia for consistency with reality. However, any errors of fact or interpretation are the responsibility of the author.

Table 13.—*Beckley area: land area by class of land, 1961*
(In thousands of acres)

Land class	25-mile area	25-to-50-mile area
Forest:		
Commercial	1,323.7	2,858.6
Noncommercial	4.8	6.5
All forest land area	1,328.5	2,865.1
Nonforest	299.2	533.8
All land	1,627.7	3,398.9

Table 14.—*Beckley area: area of commercial forest land, by ownership group and size-of-holding class, 1961*

(In thousands of acres)

Ownership group	25-mile area	25-to-50-mile area
Public	15.6	146.9
Forest industries:		
Less than 50,000 acres	26.0	52.3
50,000 acres and more	33.1	66.6
Total	59.1	118.9
Farmer-owned and miscellaneous private:		
Less than 100 acres	364.7	757.1
100 to 500 acres	214.8	446.0
500 to 50,000 acres	372.2	772.6
50,000 acres and more	297.3	617.1
Total	1,249.0	2,592.8
All ownerships	1,323.7	2,858.6

Table 15.—*Beckley area: area of commercial forest land, by forest types, 1961*

(In thousands of acres)

Forest type	25-mile area	25-to-50-mile area
White pine	14.9	32.4
Loblolly-shortleaf pine	26.7	57.2
Oak types	961.8	2,035.2
Maple, beech, birch	236.9	568.2
Yellow-poplar	29.3	56.7
Other hardwood types	54.1	108.9
All types	1,323.7	2,858.6

Table 16.—*Beckley area: area of commercial forest land by stand-volume classes, for sawtimber and other stand-size classes, 1961*

(In thousands of acres)

Stand volume/acre, in board feet[1]	All stands	Sawtimber stands	Other stands
25-MILE AREA			
Less than 1,500	549.2	61.6	487.6
1,500 to 5,000	556.1	378.3	177.8
More than 5,000	218.4	218.4	—
All classes	1,323.7	658.3	665.4
25-TO-50-MILE AREA			
Less than 1,500	1,164.1	131.2	1,032.9
1,500 to 5,000	1,210.9	834.1	376.8
More than 5,000	483.6	483.6	—
All classes	2,858.6	1,448.9	1,409.7

[1] Net volume, International ¼-inch rule.

Table 17.—*Beckley area: area of commercial forest land and volume of sawtimber and growing stock, by stand-size classes, 1961*

Stand-size class	25-mile area			25-to-50-mile area		
	Area	Sawtimber[1]	Growing stock	Area	Sawtimber[1]	Growing stock
	Thousand acres	*Million bd. ft.*	*Million cu. ft.*	*Thousand acres*	*Million bd. ft.*	*Million cu. ft.*
Sawtimber	658.3	2,922.9	881.2	1,448.9	6,487.3	2,010.1
Poletimber	363.6	438.5	297.1	797.1	970.9	690.7
Other	301.8	125.8	122.3	612.6	204.7	209.2
Total	1,323.7	3,487.2	1,300.6	2,858.6	7,662.9	2,910.0

[1] International ¼-inch rule.

Table 18.—*Beckley area: volume of sawtimber and growing stock on commercial forest land, by species, 1961*

Species	25-mile area		25-to-50-mile area	
	Saw-timber	Growing stock	Saw-timber	Growing stock
	Million bd. ft.	*Million cu. ft.*	*Million bd. ft.*	*Million cu. ft.*
Softwoods:				
Yellow pines	54.7	16.9	129.5	39.3
Hemlock	44.6	18.9	100.5	38.4
Other softwoods	28.3	13.1	83.7	35.1
Total	127.6	48.9	313.7	112.8
Hardwoods:				
White oak	191.1	83.3	413.2	178.8
Northern red oak	389.4	144.0	868.9	318.9
Chestnut oak	364.3	127.6	787.8	282.3
Other oaks	503.7	135.2	1,049.6	323.6
Hickory	390.3	144.5	819.7	313.0
Yellow birch	47.0	10.9	122.3	43.5
Sugar maple	143.8	59.3	318.9	130.8
Red maple	153.1	69.2	328.1	162.6
Beech	216.7	74.3	497.3	167.0
Basswood	148.8	51.2	302.8	107.6
Yellow-poplar	425.6	166.0	960.1	362.7
Ash, walnut, cherry	79.3	37.6	199.7	94.1
Other hardwoods	306.5	148.6	680.8	312.3
Total	3,359.6	1,251.7	7,349.2	2,797.2
All species	3,487.2	1,300.6	7,662.9	2,910.0

Table 19.—*Beckley area: volume of sawtimber on commercial forest land, by species and quality classes, 1961*[1]

(In millions of board feet)

Species	All classes	Standard lumber logs			Tie-and-timber logs[2]
		Grade 1	Grade 2	Grade 3	
	25-MILE AREA				
Softwoods:					
Yellow pines	54.7	15.6	14.4	24.7	*
White pine	25.0	5.4	8.3	11.3	*
Other softwoods	47.9	*	*	*	*
Total	127.6	21.0	22.7	36.0	*
Hardwoods:					
Select red and white oaks	580.5	63.9	117.2	256.0	143.4
Other red and white oaks	868.0	118.9	212.7	307.3	229.1
Hickory	390.3	26.9	85.9	178.8	98.7
Beech	216.7	19.7	45.5	102.1	49.4
Sugar maple	143.8	6.0	29.3	55.4	53.1
Ash, walnut, cherry	79.3	12.3	14.8	42.0	10.2
Yellow-poplar	425.6	54.9	68.5	181.7	120.5
Other hardwoods	655.4	61.2	139.9	306.9	147.4
Total	3,359.6	363.8	713.8	1,430.2	851.8
All species	3,487.2	384.8	736.5	1,466.2	851.8
	25-TO-50-MILE AREA				
Softwoods:					
Yellow pines	129.5	35.4	33.8	60.3	*
White pine	57.0	12.3	17.3	27.4	*
Other softwoods	127.2	*	*	*	*
Total	313.7	47.7	51.1	87.7	*
Hardwoods:					
Select red and white oaks	1,282.1	141.5	259.0	564.5	317.1
Other red and white oaks	1,837.4	251.3	448.7	651.0	486.4
Hickory	819.7	56.6	180.2	375.2	207.7
Beech	497.3	44.8	102.7	235.2	114.6
Sugar maple	318.9	13.9	63.8	124.8	116.4
Ash, walnut, cherry	199.7	29.7	38.8	106.0	25.2
Yellow-poplar	960.1	123.8	154.6	410.1	271.6
Other hardwoods	1,434.0	133.7	304.8	672.4	323.1
Total	7,349.2	795.3	1,552.6	3,139.2	1,862.1
All species	7,662.9	843.0	1,603.7	3,226.9	1,862.1

[1] International 1/4-inch rule.

[2] Meet minimum specifications for tie-and-timber logs but not for standard-lumber logs.

*Not applicable: spruce, hemlock, and miscellaneous softwoods were not graded into standard-lumber logs.

Table 20.—*Beckley area: volume of sawtimber on commercial forest land, by species and broad diameter classes, 1961*

(In millions of board feet[1])

Species	All classes	Diameter class (in inches)		
		14 or less	16 and 18	20 or more
	25-MILE AREA			
Softwoods:				
Yellow pines	54.7	31.8	15.3	7.6
White pine	25.0	20.9	4.1	—
Hemlock	44.6	18.4	22.6	3.6
Other softwoods	3.3	3.3	—	—
Total	127.6	74.4	42.0	11.2
Hardwoods				
White oak	191.1	76.0	47.0	68.1
Northern red oak	389.4	127.9	122.4	139.1
Chestnut oak	364.3	93.6	104.3	166.4
Other oaks	503.7	153.7	190.3	159.7
Hickory	390.3	176.4	134.1	79.8
Yellow birch	47.0	7.8	12.4	26.8
Sugar maple	143.8	34.3	34.1	75.4
Red maple	153.1	55.3	40.6	57.2
Beech	216.7	74.8	60.5	81.4
Basswood	148.8	64.8	40.8	43.2
Yellow-poplar	425.6	187.0	164.0	74.6
Ash, walnut, cherry	79.3	34.6	22.6	22.1
Other hardwoods	306.5	106.9	109.9	89.7
Total	3,359.6	1,193.1	1,083.0	1.083.5
All species	3,487.2	1,267.5	1,125.0	1,094.7
	25-TO-50-MILE AREA			
Softwoods:				
Yellow pines	129.5	75.2	36.2	18.1
White pine	57.0	47.6	9.4	—
Hemlock	100.5	41.5	50.8	8.2
Other softwoods	26.7	26.7	—	—
Total	313.7	191.0	96.4	26.3
Hardwoods:				
White oak	413.2	164.5	101.5	147.2
Northern red oak	868.9	285.3	273.2	310.4
Chestnut oak	787.8	202.4	225.5	359.9
Other oaks	1,049.6	320.3	396.5	332.8
Hickory	819.7	370.3	281.7	167.7
Yellow birch	122.3	20.3	32.3	69.7
Sugar maple	318.9	76.1	75.7	167.1
Red maple	328.1	118.5	87.1	122.5
Beech	497.3	171.8	138.9	186.6

CONTINUED

Table 20, Continued

Species	All classes	Diameter class (in inches)		
		14 or less	16 and 18	20 or more
Basswood	302.8	131.8	83.1	87.9
Yellow-poplar	960.1	421.9	369.9	168.3
Ash, walnut, cherry	199.7	87.1	56.8	55.8
Other hardwoods	680.8	237.4	244.2	199.2
Total	7,349.2	2,607.7	2,366.4	2,375.1
All species	7,662.9	2,798.7	2,462.8	2,401.4

[1] International ¼-inch rule.

Table 21.—*Elkins area: land area by class of land, 1961*

(In thousands of acres)

Land class	25-mile area	25-to-50-mile area
Forest:		
Commercial	1,042.2	2,112.8
Non-commercial	19.2	35.0
All forest land area	1,061.4	2,147.8
Nonforest	311.4	929.3
All land	1,372.8	3,077.1

Table 22.—*Elkins area: area of commercial forest land, by ownership group and size-of-holding class, 1961*

(In thousands of acres)

Ownership group	25-mile area	25-to-50-mile area
Public	256.4	485.7
Forest industries:		
Less than 50,000 acres	28.6	60.6
50,000 acres and more	36.4	77.1
Total	65.0	137.7
Farmer-owned and miscellaneous private:		
Less than 100 acres	314.3	649.4
100 to 500 acres	261.7	540.6
500 to 50,000 acres	130.4	269.6
50,000 acres and more	14.4	29.8
Total	720.8	1,489.4
All ownerships	1,042.2	2,112.8

Table 23.—*Elkins area: area of commercial forest land, by forest types, 1961*

(In thousands of acres)

Forest type	25-mile area	25-to-50-mile area
White pine	17.3	30.2
Loblolly-shortleaf pine	49.7	106.8
Oak types	648.1	1,337.5
Maple, beech, birch	288.9	556.0
Yellow-poplar	3.6	6.7
Other hardwood types	34.6	75.6
All types	1,042.2	2,112.8

Table 24.—*Elkins area: area of commercial forest land by stand-volume classes for sawtimber and other stand-size classes, 1961*

(In thousands of acres)

Stand volume/acre, in board feet[1]	All stands	Sawtimber stands	Other stands
25-MILE AREA			
Less than 1,500	429.4	23.8	405.6
1,500 to 5,000	440.5	335.8	104.7
More than 5,000	172.3	172.3	—
All classes	1,042.2	531.9	510.3
25-TO-50-MILE AREA			
Less than 1,500	907.1	46.3	860.8
1,500 to 5,000	871.4	652.9	218.5
More than 5,000	334.3	334.3	—
All classes	2,112.8	1,033.5	1,079.3

[1] Net volume, International ¼-inch rule.

Table 25.—*Elkins area: area of commercial forest land and volume of sawtimber and growing stock by stand-size classes, 1961*

Stand-size class	25-mile area			25-to-50-mile area		
	Area	Sawtimber[1]	Growing stock	Area	Sawtimber[1]	Growing stock
	Thousand acres	*Million bd. ft.*	*Million cu. ft.*	*Thousand acres*	*Million bd. ft.*	*Million cu. ft.*
Sawtimber	531.9	2,380.0	764.2	1,033.5	4,717.4	1,556.1
Poletimber	314.3	350.1	305.3	643.4	711.8	589.2
Other	196.0	59.0	53.3	435.9	107.9	96.2
Total	1,042.2	2,789.1	1,122.8	2,112.8	5,537.1	2,241.5

[1] International ¼-inch rule.

Table 26.—*Elkins area: volume of sawtimber and growing stock on commercial forest land by species, 1961*

Species	25-mile area		25-to-50-mile area	
	Sawtimber	Growing stock	Sawtimber	Growing stock
	Million bd. ft.	*Million cu. ft.*	*Million bd. ft.*	*Million cu. ft.*
Softwoods:				
Yellow pines	91.8	34.4	174.9	70.6
Hemlock	66.8	18.9	128.1	32.5
Other softwoods	81.3	26.7	153.2	49.8
Total	239.9	80.0	456.2	152.9
Hardwoods:				
White oak	234.6	85.5	436.5	158.4
Northern red oak	355.4	129.7	680.5	246.0
Chestnut oak	305.6	133.1	671.1	289.9
Other oaks	199.9	59.2	451.8	147.2
Hickory	153.4	68.0	310.4	139.7
Yellow birch	57.1	32.9	108.1	60.3
Sugar maple	189.9	79.4	344.2	159.2
Red maple	101.7	73.6	200.7	144.3
Beech	219.4	78.8	394.3	144.8
Basswood	93.2	33.6	178.0	64.7
Yellow-poplar	244.7	86.2	477.8	175.4
Ash, walnut, cherry	185.0	84.8	381.6	162.6
Other hardwoods	209.3	98.0	445.9	196.1
Total	2,549.2	1,042.8	5,080.9	2,088.6
All species	2,789.1	1,122.8	5,537.1	2,241.5

Table 27.—*Elkins area: volume of sawtimber on commercial forest land, by species and quality classes, 1961*

(In millions of board feet)[1]

Species	All classes	Standard lumber logs			Tie-and-timber logs[2]
		Grade 1	Grade 2	Grade 3	
			25-MILE AREA		
Softwoods:					
Yellow pines	91.8	11.7	22.9	57.2	*
White pine	27.7	6.1	9.1	12.5	*
Other softwoods	120.4	*	*	*	*
Total	239.9	17.8	32.0	69.7	*
Hardwoods:					
Select red and white oaks	590.0	68.1	103.8	272.1	146.0
Other red and white oaks	505.5	57.5	92.4	211.3	144.3
Hickory	153.4	11.8	24.9	68.2	48.5
Beech	219.4	17.1	35.9	112.3	54.1
Sugar maple	189.9	11.3	29.1	91.9	57.6
Ash, walnut, cherry	185.0	20.1	44.5	102.7	17.7
Yellow-poplar	244.7	34.2	37.3	105.2	68.0
Other hardwoods	461.3	37.3	77.2	236.6	110.2
Total	2,549.2	257.4	445.1	1,200.3	646.4
All species	2,789.1	275.2	477.1	1,270.0	646.4
			25-TO-50-MILE AREA		
Softwoods:					
Yellow pines	174.9	22.0	43.7	109.2	*
White pine	56.1	12.2	18.5	25.4	*
Other softwoods	225.2	*	*	*	*
Total	456.2	34.2	62.2	134.6	*
Hardwoods:					
Select red and white oaks	1,117.0	129.0	197.1	514.4	276.5
Other red and white oaks	1,122.9	127.5	204.7	470.3	320.4
Hickory	310.4	23.8	50.3	138.1	98.2
Beech	394.3	30.8	64.9	201.1	97.5
Sugar maple	344.2	20.5	53.1	165.7	104.9
Ash, walnut, cherry	381.6	41.5	91.8	212.0	36.3
Yellow-poplar	477.8	66.9	72.8	205.3	132.8
Other hardwoods	932.7	75.2	155.6	478.7	223.2
Total	5,080.9	515.2	890.3	2,385.6	1,289.8
All species	5,537.1	549.4	952.5	2,520.2	1,289.8

[1] International ¼-inch rule.

[2] Meet minimum specifications for tie-and-timber logs but not for standard-lumber logs.

*Not applicable: spruce, hemlock, and miscellaneous softwoods were not graded into standard-lumber logs.

Table 28.—*Elkins area: volume of sawtimber on commercial forest land, by species and broad diameter classes, 1961*

(In millions of board feet)[1]

Species	All classes	Diameter class (in inches)		
		14 or less	16 and 18	20 or more
25-MILE AREA				
Softwoods:				
Yellow pines	91.8	76.0	11.4	4.4
White pine	27.7	12.3	9.9	5.5
Hemlock	66.8	25.4	20.0	21.4
Other softwoods	53.6	39.9	13.4	0.3
Total	239.9	153.6	54.7	31.6
Hardwoods:				
White oak	234.6	109.2	63.1	62.3
Northern red oak	355.4	118.1	123.4	113.9
Chestnut oak	305.6	138.9	81.3	85.4
Other oaks	199.9	70.5	66.0	63.4
Hickory	153.4	65.2	44.5	43.7
Yellow birch	57.1	19.8	15.2	22.1
Sugar maple	189.9	59.3	51.3	79.3
Red maple	101.7	47.7	30.9	23.1
Beech	219.4	87.0	69.4	63.0
Basswood	93.2	28.5	31.0	33.7
Yellow-poplar	244.7	116.1	85.7	42.9
Ash, Walnut, cherry	185.0	96.8	57.3	30.9
Other hardwoods	209.3	101.8	60.0	47.5
Total	2,549.2	1,058.9	779.1	711.2
All species	2,789.1	1,212.5	833.8	742.8
25-TO-50-MILE AREA				
Softwoods:				
Yellow pines	174.9	147.4	20.5	7.0
White pine	56.1	24.8	20.1	11.2
Hemlock	128.1	49.0	38.5	40.6
Other softwoods	97.1	72.5	24.2	0.4
Total	456.2	293.7	103.3	59.2
Hardwoods:				
White oak	436.5	203.2	117.4	115.9
Northern red oak	680.5	225.9	235.8	218.8
Chestnut oak	671.1	306.6	177.6	186.9
Other oaks	451.8	159.3	149.2	143.3
Hickory	310.4	131.9	90.0	88.5
Yellow birch	108.1	37.3	28.8	42.0
Sugar maple	344.2	107.3	93.9	143.0

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Table 28, Continued

Species	All classes	Diameter class (in inches)		
		14 or less	16 and 18	20 or more
Red maple	200.7	93.7	61.0	46.0
Beech	394.3	156.9	128.1	109.3
Basswood	178.0	54.5	59.2	64.3
Yellow-poplar	477.8	226.3	167.4	84.1
Ash, walnut, cherry	381.6	199.8	117.8	64.0
Other hardwoods	445.9	216.5	127.7	101.7
Total	5,080.9	2,119.2	1,553.9	1,407.8
All species	5,537.1	2,412.9	1,657.2	1,467.0

[1] International ¼-inch rule.

Table 29.—*Huntington area: land area by class of land, 1961*

(In thousands of acres)

Land class	25-mile area	25-to-50-mile area
Forest:		
Commercial	557.9	406.8
Noncommercial	.1	0
All forest land area	558.0	406.8
Nonforest	225.4	96.8
All land	783.4	503.6

Table 30.—*Huntington area: area of commercial forest land, by ownership group and size-of-holding class, 1961*

(In thousands of acres)

Ownership group	25-mile area	25-to-50-mile area
Public	25.9	5.7
Forest industries:		
Less than 50,000 acres	6.2	4.7
50,000 acres and more	7.8	6.0
Total	14.0	10.7
Farmer-owned and miscellaneous private:		
Less than 100 acres	243.5	183.5
100 to 500 acres	220.1	165.9
500 to 50,000 acres	54.4	41.0
50,000 acres and more	—	—
Total	518.0	390.4
All ownerships	557.9	406.8

Table 31.—*Huntington area: area of commercial forest land by forest types, 1961*

(In thousands of acres)

Forest type	25-mile area	25-to-50-mile area
White pine	2.8	1.8
Loblolly-shortleaf pine	55.5	38.6
Oak types	346.3	253.3
Maple, beech, birch	84.2	61.6
Yellow-poplar	14.6	9.2
Other hardwood types	54.5	42.3
All types	557.9	406.8

Table 32.—*Huntington area: area of commercial forest land by stand-volume classes for sawtimber and other stand-size classes, 1961*

(In thousands of acres)

Stand volume/acre, in board feet[1]	All stands	Sawtimber stands	Other stands
	25-MILE AREA		
Less than 1,500	292.0	16.6	275.4
1,500 to 5,000	187.3	151.2	36.1
More than 5,000	78.6	78.6	—
All classes	557.9	246.4	311.5
	25-TO-50-MILE AREA		
Less than 1,500	216.4	11.8	204.6
1,500 to 5,000	134.5	107.6	26.9
More than 5,000	55.9	55.9	—
All classes	406.8	175.3	231.5

[1] Net volume, International ¼-inch rule.

Table 33.—*Huntington area: area of commercial forest land and volume of sawtimber and growing stock by stand-size classes, 1961*

Stand-size class	25-mile area			25-to-50-mile area		
	Area	Saw-timber[1]	Growing Stock	Area	Saw-timber[1]	Growing Stock
	Thousand acres	*Million bd. ft.*	*Million cu. ft.*	*Thousand acres*	*Million bd. ft.*	*Million cu. ft.*
Sawtimber	246.4	937.2	304.2	175.3	674.2	220.5
Poletimber	134.6	150.0	112.5	97.6	110.1	85.1
Other	176.9	90.8	20.4	133.9	69.4	15.9
Total	557.9	1,178.0	437.1	406.8	853.7	321.5

[1] International ¼-inch rule.

Table 34.—*Huntington area: volume of sawtimber and growing stock on commercial forest land by species, 1961*

Species	25-mile area		25-to-50-mile area	
	Saw-timber	Growing stock	Saw-timber	Growing stock
	Million bd. ft.	*Million cu. ft.*	*Million bd. ft.*	*Million cu. ft.*
Softwoods:				
Yellow pines	49.6	20.2	36.1	14.9
Hemlock	2.4	1.0	2.0	.9
Other softwoods	4.2	1.1	2.7	.7
Total	56.2	22.3	40.8	16.5
Hardwoods:				
White oak	161.9	61.9	113.3	44.1
Northern red oak	145.0	51.4	109.7	36.4
Chestnut oak	98.9	32.4	73.2	24.1
Other oaks	213.8	59.9	140.4	38.9
Hickory	88.2	47.6	60.8	35.1
Yellow birch	1.2	.5	1.0	.6
Sugar maple	45.3	16.8	33.5	12.4
Red maple	14.0	10.2	9.6	7.7
Beech	72.9	22.5	62.4	19.9
Basswood	15.0	6.1	11.0	5.6
Yellow-poplar	82.4	31.1	61.3	23.0
Ash, walnut, cherry	68.5	28.4	48.2	20.7
Other hardwoods	114.7	46.0	88.5	36.5
Total	1,121.8	414.8	812.9	305.0
All species	1,178.0	437.1	853.7	321.5

Table 35.—*Huntington area: volume of sawtimber on commercial forest land by species and quality classes, 1961*

(In millions of board feet)[1]

Species	All classes	Standard lumber logs			Tie-and-timber logs[2]
		Grade 1	Grade 2	Grade 3	
		25-MILE AREA			
Softwoods:					
Yellow pines	49.6	6.8	11.0	31.8	*
White pine	4.2	1.2	1.2	1.8	*
Other softwoods	2.4	*	*	*	*
Total	56.2	8.0	12.2	33.6	*
Hardwoods:					
Select red and white oaks	306.9	37.1	73.1	114.8	81.9
Other red and white oaks	312.7	40.7	65.0	99.7	107.3
Hickory	88.2	7.8	19.0	34.3	27.1
Beech	72.9	5.4	11.2	33.8	22.5
Sugar maple	45.3	3.9	6.0	20.7	14.7
Ash, walnut, cherry	68.5	6.9	16.7	34.5	10.4
Yellow-poplar	82.4	8.5	15.0	37.0	21.9
Other hardwoods	144.9	10.7	22.4	67.2	44.6
Total	1,121.8	121.0	228.4	442.0	330.4
All species	1,178.0	129.0	240.6	475.6	330.4
		25-TO-50-MILE AREA			
Softwoods:					
Yellow pines	36.1	4.9	8.0	23.2	*
White pine	2.7	.8	.8	1.1	*
Other softwoods	2.0	*	*	*	*
Total	40.8	5.7	8.8	24.3	*
Hardwoods:					
Select red and white oaks	223.0	27.0	53.1	83.4	59.5
Other red and white oaks	213.6	27.8	44.4	68.1	73.3
Hickory	60.8	5.3	13.1	23.7	18.7
Beech	62.4	4.6	9.6	29.0	19.2
Sugar maple	33.5	2.9	4.4	15.3	10.9
Ash, walnut, cherry	48.2	4.9	11.8	24.2	7.3
Yellow-poplar	61.3	6.3	11.2	27.5	16.3
Other hardwoods	110.1	8.2	17.0	51.1	33.8
Total	812.9	87.0	164.6	322.3	239.0
All species	853.7	92.7	173.4	346.6	239.0

[1] International ¼-inch rule.

[2] Meet minimum specifications for tie-and-timber logs but not for standard-lumber logs.

*Not applicable: spruce, hemlock, and miscellaneous softwoods were not graded into standard-lumber logs.

Table 36.—*Huntington area: volume of sawtimber on commercial forest land, by species and broad diameter classes, 1961*

(In millions of board feet)[1]

Species	All classes	Diameter class (in inches) 14 or less	16 and 18	20 or more
	25-MILE AREA			
Softwoods:				
Yellow pines	49.6	41.1	6.8	1.7
White pine	4.2	1.7	2.5	0
Hemlock	2.4	1.7	.7	0
Total	56.2	44.5	10.0	1.7
Hardwoods:				
White oak	161.9	73.2	39.7	49.0
Northern red oak	145.0	55.9	36.0	53.1
Chestnut oak	98.9	44.3	29.1	25.5
Other oaks	213.8	78.4	65.2	70.2
Hickory	88.2	42.8	20.9	24.5
Yellow birch	1.2	.9	.3	0
Sugar maple	45.3	14.2	12.1	19.0
Red maple	14.0	7.5	4.6	1.9
Beech	72.9	21.8	22.7	28.4
Basswood	15.0	9.6	4.1	1.3
Yellow-poplar	82.4	34.9	27.7	19.8
Ash, walnut, cherry	68.5	30.0	24.4	14.1
Other hardwoods	114.7	48.1	31.8	34.8
Total	1,121.8	461.6	318.6	341.6
All species	1,178.0	506.1	328.6	343.3
	25-TO-50-MILE AREA			
Softwoods:				
Yellow pines	36.1	29.9	5.0	1.2
White pine	2.7	1.1	1.6	0
Hemlock	2.0	1.5	.5	0
Total	40.8	32.5	7.1	1.2
Hardwoods:				
White oak	113.3	51.2	27.8	34.3
Northern red oak	109.7	42.3	27.2	40.2
Chestnut oak	73.2	32.8	21.5	18.9
Other oaks	140.4	51.5	42.8	46.1
Hickory	60.8	29.5	14.4	16.9
Yellow birch	1.0	.8	.2	0
Sugar maple	33.5	10.5	9.0	14.0
Red maple	9.6	5.1	3.2	1.3
Beech	62.4	18.7	19.4	24.3
Basswood	11.0	7.0	3.1	.9

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Table 36, Continued

Species	All classes	Diameter class (in inches) 14 or less	16 and 18	20 or more
Yellow-poplar	61.3	26.0	20.6	14.7
Ash, walnut, cherry	48.2	21.1	17.2	9.9
Other hardwoods	88.5	37.1	24.5	26.9
Total	812.9	333.6	230.9	248.4
All species	853.7	366.1	238.0	249.6

[1] International ¼-inch rule.

Table 37.—***Parkersburg area: land area by class of land, 1961***

(In thousands of acres)

Land class	25-mile area	25-to-50-mile area
Forest:		
Commercial	696.5	765.4
Noncommercial	1.4	2.0
All forest land area	697.9	767.4
Nonforest	356.2	308.3
All land	1,054.1	1,075.7

Table 38.—***Parkersburg area: area of commercial forest land, by ownership group and size-of-holding class, 1961***

(In thousands of acres)

Ownership group	25-mile area	25-to-50-mile area
Public	0.1	0
Forest industries:		
Less than 50,000 acres	7.5	8.6
50,000 acres and more	9.5	11.0
Total	17.0	19.6
Farmer-owned and miscellaneous private:		
Less than 100 acres	319.3	350.5
100 to 500 acres	288.8	317.0
500 to 50,000 acres	71.3	78.3
50,000 acres and more	—	—
Total	679.4	745.8
All ownerships	696.5	765.4

Table 39.—*Parkersburg area: area of commercial forest land, by forest types, 1961*

(In thousands of acres)

Forest type	25-mile area	25-to-50-mile area
White pine	3.6	3.1
Loblolly-shortleaf pine	69.4	75.6
Oak types	426.6	471.2
Maple, beech, birch	111.0	119.9
Yellow-poplar	19.8	19.4
Other hardwood types	66.1	76.2
All types	696.5	765.4

Table 40.—*Parkersburg area: area of commercial forest land, by stand-volume classes for sawtimber and other stand-size classes, 1961*

(In thousands of acres)

Stand volume/acre, in board feet[1]	All stands	Sawtimber stands	Other stands
	25-MILE AREA		
Less than 1,500	351.9	21.8	330.1
1,500 to 5,000	241.6	198.3	43.3
More than 5,000	103.0	103.0	—
All classes	696.5	323.1	373.4
	25-TO-50-MILE AREA		
Less than 1,500	396.8	23.2	373.6
1,500 to 5,000	259.4	210.3	49.1
More than 5,000	109.2	109.2	—
All classes	765.4	342.7	422.7

[1] Net volume, International ¼-inch rule.

Table 41.—*Parkersburg area: area of commercial forest land and volume of sawtimber and growing stock by stand-size classes, 1961*

Stand-size class	25-mile area			25-to-50-mile area		
	Area	Sawtimber[1]	Growing stock	Area	Sawtimber[1]	Growing stock
	Thousand acres	*Million bd. ft.*	*Million cu. ft.*	*Thousand acres*	*Million bd. ft.*	*Million cu. ft.*
Sawtimber	323.1	1,208.3	396.1	342.7	1,311.4	427.4
Poletimber	164.3	173.4	129.8	176.4	189.7	143.5
Other	209.1	124.2	27.8	246.3	120.9	27.0
Total	696.5	1,505.9	553.7	765.4	1,622.0	597.9

[1] International ¼-inch rule.

Table 42.—*Parkersburg area: volume of sawtimber and growing stock on commercial forest land by species, 1961*

Species	25-mile area		25-to-50-mile area	
	Sawtimber	Growing stock	Sawtimber	Growing stock
	Million bd. ft.	*Million cu. ft.*	*Million bd. ft.*	*Million cu. ft.*
Softwoods:				
Yellow pines	57.6	22.6	64.2	25.1
Hemlock	2.9	1.3	2.9	1.9
Other softwoods	5.2	1.4	4.6	1.4
Total	65.7	25.3	71.7	28.4
Hardwoods:				
White oak	211.3	79.4	223.1	84.6
Northern red oak	187.5	70.9	212.1	75.3
Chestnut oak	126.7	41.4	135.7	45.8
Other oaks	285.4	79.8	290.1	81.3
Hickory	117.8	60.3	126.2	65.7
Yellow birch	1.1	.5	1.6	.7
Sugar maple	58.0	20.9	64.0	22.3
Red maple	20.0	13.6	20.3	14.7
Beech	83.8	24.3	102.8	30.8
Basswood	20.8	10.1	22.0	10.8
Yellow-poplar	100.9	37.2	111.1	40.7
Ash, walnut, cherry	90.8	35.4	92.7	37.2
Other hardwoods	136.1	54.6	148.6	59.6
Total	1,440.2	528.4	1,550.3	569.5
All species	1,505.9	553.7	1,622.0	597.9

Table 43.—*Parkersburg area: volume of sawtimber on commercial forest land by species and quality classes, 1961*

(In millions of board feet)[1]

Species	All classes	Standard lumber logs			Tie-and-timber logs[2]
		Grade 1	Grade 2	Grade 3	
	25-MILE AREA				
Softwoods:					
Yellow pines	57.6	7.8	12.8	37.0	*
White pine	5.2	1.5	1.5	2.2	*
Other softwoods	2.9	*	*	*	*
Total	65.7	9.3	14.3	39.2	*
Hardwoods:					
Select red and white oaks	398.8	48.2	94.9	149.2	106.5
Other red and white oaks	412.1	53.6	85.7	131.5	141.3
Hickory	117.8	10.4	25.4	45.8	36.2
Beech	83.8	6.2	12.9	38.9	25.8
Sugar maple	58.0	5.0	7.7	26.5	18.8
Ash, walnut, cherry	90.8	9.2	22.1	45.7	13.8
Yellow-poplar	100.9	10.4	18.4	45.3	26.8
Other hardwoods	178.0	13.2	27.5	82.5	54.8
Total	1,440.2	156.2	294.6	565.4	424.0
All species	1,505.9	165.5	308.9	604.6	424.0
	25-TO-50-MILE AREA				
Softwoods:					
Yellow pines	64.2	8.7	14.3	41.2	*
White pines	4.6	1.4	1.3	1.9	*
Other softwoods	2.9	*	*	*	*
Total	71.7	10.1	15.6	43.1	*
Hardwoods:					
Select red and white oaks	435.2	52.6	103.6	162.8	116.2
Other red and white oaks	425.8	55.4	88.6	135.8	146.0
Hickory	126.2	11.1	27.3	49.1	38.7
Beech	102.8	7.6	15.8	47.7	31.7
Sugar maple	64.0	5.5	8.4	29.3	20.8
Ash, walnut, cherry	92.7	9.4	22.6	46.6	14.1
Yellow-poplar	111.1	11.4	20.2	49.9	29.6
Other hardwoods	192.5	14.3	29.7	89.3	59.2
Total	1,550.3	167.3	316.2	610.5	456.3
All species	1,622.0	177.4	331.8	653.6	456.3

[1] International ¼-inch rule.

[2] Meet minimum specifications for tie-and-timber logs but not for standard-lumber logs.

* Not applicable: spruce, hemlock, and miscellaneous softwoods were not graded into standard-lumber logs.

Table 44.—*Parkersburg area: volume of sawtimber on commercial forest land by species and broad diameter classes, 1961*

(In millions of board feet)[1]

Species	All classes	Diameter class (in inches)		
		14 or less	16 and 18	20 or more
	25-MILE AREA			
Softwoods:				
Yellow pines	57.6	47.7	7.9	2.0
White pine	5.2	2.1	3.1	0
Hemlock	2.9	2.1	.8	0
Total	65.7	51.9	11.8	2.0
Hardwoods:				
White oak	211.3	95.5	51.8	64.0
Northern red oak	187.5	72.3	46.5	68.7
Chestnut oak	126.7	56.7	37.3	32.7
Other oaks	285.4	104.7	87.0	93.7
Hickory	117.8	57.1	27.9	32.8
Yellow birch	1.1	.8	.3	0
Sugar maple	58.0	18.2	15.5	24.3
Red maple	20.0	10.7	6.5	2.8
Beech	83.8	25.1	26.1	32.6
Basswood	20.8	13.3	5.8	1.7
Yellow-poplar	100.9	42.8	33.9	24.2
Ash, walnut, cherry	90.8	39.8	32.4	18.6
Other hardwoods	136.1	57.0	37.7	41.4
Total	1,440.2	594.0	408.7	437.5
All species	1,505.9	645.9	420.5	439.5
	25-TO-50-MILE AREA			
Softwoods:				
Yellow pines	64.2	53.1	8.9	2.2
White pine	4.6	1.8	2.8	0
Hemlock	2.9	2.1	.8	.0
Total	71.7	57.0	12.5	2.2
Hardwoods:				
White oak	223.1	100.9	54.7	67.5
Northern red oak	212.1	81.8	52.6	77.7
Chestnut oak	135.7	60.7	40.0	35.0
Other oaks	290.1	106.4	88.4	95.3
Hickory	126.2	61.2	29.9	35.1
Yellow birch	1.6	1.2	.4	0
Sugar maple	64.0	20.1	17.1	26.8
Red maple	20.3	10.9	6.6	2.8
Beech	102.8	30.8	32.0	40.0
Basswood	22.0	14.1	6.1	1.8

CONTINUED

Table 44, Continued

Species	All classes	Diameter class (in inches)		
		14 or less	16 and 18	20 or more
Yellow-poplar	111.1	47.1	37.3	26.7
Ash, walnut, cherry	92.7	40.6	33.1	19.0
Other hardwoods	148.6	62.3	41.2	45.1
Total	1,550.3	638.1	439.4	472.8
All species	1,622.0	695.1	451.9	475.0

[1] International ¼-inch rule.

Table 45.—*Richwood area: land areas by class of land, 1961*

(In thousands of acres)

Land class	25-mile area	25-to-50-mile area
Forest:		
Commercial	1,629.7	1,437.5
Noncommercial	24.2	13.1
All forest land area	1,653.9	1,450.6
Nonforest	374.2	409.4
All land	2,028.1	1,860.0

Table 46.—*Richwood area: area of commercial forest land, by ownership group and size-of-holding class, 1961*

(In thousands of acres)

Ownership group	25-mile area	25-to-50-mile area
Public	485.0	177.2
Forest industries:		
Less than 50,000 acres	30.9	36.7
50,000 acres and more	39.3	46.7
Total	70.2	83.4
Farmer-owned and miscellaneous private:		
Less than 100 acres	367.7	439.1
100 to 500 acres	256.4	329.0
500 to 50,000 acres	276.4	273.2
50,000 acres and more	174.0	135.6
Total	1,074.5	1,176.9
All ownerships	1,629.7	1,437.5

Table 47.—*Richwood area: area of commercial forest land, by forest types, 1961*

(In thousands of acres)

Forest type	25-mile area	25-to-50-mile area
White pine	32.4	18.9
Loblolly-shortleaf pine	63.3	53.0
Oak types	990.6	968.8
Maple, beech, birch	476.4	325.3
Yellow-poplar	17.5	18.5
Other hardwood types	49.5	53.0
All types	1,629.7	1,437.5

Table 48.—*Richwood area: area of commercial forest land, by stand-volume classes for sawtimber and other stand-size classes, 1961*

(In thousands of acres)

Stand volume/acre, in board feet[1]	All stands	Sawtimber stands	Other stands
25-MILE AREA			
Less than 1,500	657.7	53.6	604.1
1,500 to 5,000	690.3	496.5	193.8
More than 5,000	281.7	281.7	—
All classes	1,629.7	831.8	797.9
25-TO-50-MILE AREA			
Less than 1,500	591.3	45.9	545.4
1,500 to 5,000	609.3	448.5	160.8
More than 5,000	236.9	236.9	—
All classes	1,437.5	731.3	706.2

[1] Net volume, international ¼-inch rule.

Table 49.—*Richwood area: area of commercial forest land, and volume of sawtimber and growing stock by stand-size classes, 1961*

Stand-size class	25-mile area			25-to-50-mile area		
	Area	Saw timber[1]	Growing stock	Area	Saw timber[1]	Growing stock
	Thousand acres	*Million bd. ft.*	*Million cu. ft.*	*Thousand acres*	*Million bd. ft.*	*Million cu. ft.*
Sawtimber	831.8	3,904.9	1,303.8	731.3	3,334.5	1,036.1
Poletimer	496.4	558.0	442.8	406.5	477.4	375.0
Other	301.5	79.8	90.9	299.7	108.2	93.6
Total	1,629.7	4,542.7	1,837.5	1,437.5	3,920.1	1,504.7

[1] International ¼-inch rule.

Table 50.—*Richwood area: volume of sawtimber and growing stock on commercial forest land by species, 1961*

Species	25-mile area		25-to-50-mile area	
	Saw-timber	Growing stock	Saw-timber	Growing stock
	Million bd. ft.	*Million cu. ft.*	*Million bd. ft.*	*Million cu. ft.*
Softwoods:				
Yellow pines	110.9	37.6	96.6	36.2
Hemlock.	120.0	34.8	69.0	20.9
Other softwoods	127.3	46.8	79.0	26.5
Total	358.2	119.2	244.6	83.6
Hardwoods:				
White oak	258.7	106.1	297.4	110.3
Northern red oak	541.6	199.8	473.7	170.1
Chestnut oak	480.3	199.0	427.1	169.9
Other oaks	430.2	140.6	405.4	114.3
Hickory	338.9	139.4	310.0	122.7
Yellow birch	113.5	54.8	63.6	29.3
Sugar maple	256.1	112.8	228.0	95.8
Red maple	184.8	116.1	151.2	90.5
Beech	348.3	125.4	280.3	95.7
Basswood	159.6	60.0	149.6	51.6
Yellow-poplar	451.6	169.7	387.4	145.1
Ash, walnut, cherry	243.3	109.1	189.4	86.5
Other hardwoods	377.6	185.5	312.4	139.3
Total	4,184.5	1,718.3	3,675.5	1,421.1
All species	4,542.7	1,837.5	3,920.1	1,504.7

Table 51.—*Richwood area: volume of sawtimber on commercial forest land, by species and quality classes, 1961*

(In millions of board feet)[1]

Species	All classes	Standard lumber logs Grade 1	Standard lumber logs Grade 2	Standard lumber logs Grade 3	Tie-and-timber logs[2]
25-MILE AREA					
Softwoods:					
Yellow pines	110.9	20.2.	27.9	62.8	*
White pine	39.2	8.6	12.9	17.7	*
Other softwoods	208.1	*	*	*	*
Total	358.2	28.8	40.8	80.5	*
Hardwoods:					
Select red and white oaks	800.3	90.9	154.2	356.3	198.9
Other red and white oaks	910.5	116.4	200.4	343.4	250.3
Hickory	338.9	24.2	69.1	153.5	92.1
Beech	348.3	29.3	64.7	170.1	84.2
Sugar maple	256.1	13.7	44.7	112.2	85.5
Ash, walnut, cherry	243.3	29.4	55.1	131.9	26.9
Yellow-poplar	451.6	59.7	71.6	193.5	126.8
Other hardwoods	835.5	74.4	163.1	404.7	193.3
Total	4,184.5	438.0	822.9	1,865.6	1,058.0
All species	4,542.7	466.8	863.7	1,946.1	1,058.0
25-TO-50-MILE AREA					
Softwoods:					
Yellow pines	96.6	15.4	24.4	56.8	*
White pine	37.9	8.2	12.5	17.2	*
Other softwoods	110.1	*	*	*	*
Total	244.6	23.6	36.9	74.0	*
Hardwoods:					
Select red and white oaks	771.1	87.6	140.7	352.3	190.5
Other red and white oaks	832.5	102.6	173.3	326.9	229.7
Hickory	310.0	22.6	59.3	140.1	88.0
Beech	280.3	22.9	49.7	140.5	67.2
Sugar maple	228.0	12.5	37.9	104.9	72.7
Ash, walnut, cherry	189.4	22.1	43.8	104.6	18.9
Yellow-poplar	387.4	52.5	60.4	166.0	108.5
Other hardwoods	676.8	57.7	124.7	336.3	158.1
Total	3,675.5	380.5	689.8	1,671.6	933.6
All species	3,920.1	404.1	726.7	1,745.6	933.6

[1] International ¼-inch rule.

[2] Meet minimum specifications for tie-and-timber logs but not for standard-lumber logs.

* Not applicable: spruce, hemlock, and miscellaneous softwoods were not graded into standard-lumber logs.

Table 52.—*Richwood area: volume of sawtimber on commercial forest land by species and broad diameter classes, 1961*

(In millions of board feet)

Species	All classes	Diameter class (in inches)		
		14 or less	16 and 18	20 or more
25-MILE AREA				
Softwoods:				
Yellow pines	110.9	77.3	21.8	11.8
White pine	39.2	21.8	11.6	5.8
Hemlock	120.0	44.8	37.3	37.9
Other softwoods	88.1	65.6	22.1	.4
Total	358.2	209.5	92.8	55.9
Hardwoods:				
White oak	258.7	114.2	66.5	78.0
Northern red oak	541.6	177.8	176.3	187.5
Chestnut oak	480.3	171.2	135.9	173.2
Other oaks	430.2	138.3	155.4	136.5
Hickory	338.9	152.9	109.7	76.3
Yellow birch	113.5	28.0	29.0	56.5
Sugar maple	256.1	72.4	70.2	113.5
Red maple	184.8	69.3	55.1	60.4
Beech	348.3	134.5	120.1	93.7
Basswood	159.6	64.3	47.0	48.3
Yellow-poplar	451.6	210.4	166.5	74.7
Ash, walnut, cherry	243.3	121.0	80.7	41.6
Other hardwoods	377.6	162.0	122.7	92.9
Total	4,184.5	1,616.3	1,335.1	1,233.1
All species	4,542.7	1,825.8	1,427.9	1,289.0
25-TO-50-MILE AREA				
Softwoods:				
Yellow pines	96.6	76.3	14.5	5.8
White pine	37.9	20.8	11.7	5.4
Hemlock	69.0	27.3	24.9	16.8
Other softwoods	41.1	31.2	9.7	.2
Total	244.6	155.6	60.8	28.2
Hardwoods:				
White oak	297.4	132.9	78.4	86.1
Northern red oak	473.7	157.0	160.3	156.4
Chestnut oak	427.1	167.4	115.3	144.4
Other oaks	405.4	132.9	143.9	128.6
Hickory	310.0	135.4	98.7	75.9
Yellow birch	63.6	18.8	17.1	27.7
Sugar maple	228.0	66.9	58.5	102.6
Red maple	151.2	65.9	42.9	42.4

CONTINUED

Table 52, Continued

Species	All classes	Diameter class (in inches)		
		14 or less	16 and 18	20 or more
Beech	280.3	105.5	81.3	93.5
Basswood	149.6	52.8	46.4	50.4
Yellow-poplar	387.4	176.9	141.7	68.8
Ash, walnut, cherry	189.4	96.4	56.4	36.6
Other hardwoods	312.4	133.9	98.2	80.3
Total	3,675.5	1,442.7	1,139.1	1,093.7
All species	3,920.1	1,598.3	1,199.9	1,121.9

[1] International ¼-inch rule.

Table 53.—*Estimated logging costs for sawtimber and pulpwood for selected areas in West Virginia*[1]

Area	Logging cost	
	Sawlogs,/1,000 board feet	Pulpwood,/Standard cord
Beckley:		
25-mile	$32.50	$15.00
25-to-50-mile[2]	34.15	15.70
Elkins:		
25-mile	28.35	13.55
25-to-50-mile[2]	37.00	16.50
Huntington:		
25-mile	34.20	15.35
25-to-50-mile[2]	33.25	15.15
Parkersburg:		
25-mile	36.30	16.05
25-to-50-mile[2]	38.50	16.95
Richwood:		
25-mile	31.00	14.40
25-to-50-mile[2]	33.30	15.40

[1] Estimates of logging costs are based on West Virginia Forest Products Market Information reports, published by U. S. Dept. of Agriculture and West Virginia Dept. of Agriculture, and analysis of regional factors affecting logging costs (author's estimates).

[2] Includes allowance for additional hauling distance to central location of $2.50/1,000 board feet for sawlogs and $1.00/standard cord for pulpwood.

Table 54.—*Estimated truck and rail freight rates for lumber, from selected locations in West Virginia to major market centers*

(In cents/100 pounds)

Destination	Origin							
	Beckley		Elkins		Huntington		Richwood	
	Truck	Rail	Truck	Rail	Truck	Rail	Truck	Rail[1]
Hickory, N. C.	36.0	51.5	45.0	61.5	43.0	45.5	42.0	84.0
Thomasville, N. C.	33.0	47.5	41.0	54.5	42.0	45.5	41.0	78.0
Roanoke, Va.	23.0	28.5	28.0	36.5	36.0	34.5	25.0	42.5
Winchester, Va.	40.0	34.5	25.0	31.5	43.0	42.5	36.0	36.5
Charleston, W. Va.	21.0	23.5	28.0	28.5	21.0	18.5	21.0	—

Source: Rail rates: Transportation and Storage Service Division, Commodity Stabilization Service, U. S. Department of Agriculture. Truck rates: Motor Tariff Bureau of West Virginia, Inc.

[1] Given as rates for particle-board.

Table 55.—*Estimated truck and rail freight rates for particle-board from selected locations in West Virginia to major market centers*

(In cents/100 pounds)

Destination	Origin					
	Beckley		Elkins		Richwood	
	Truck	Rail	Truck	Rail	Truck	Rail
Hickory, N. C.	36.0	54.5	45.0	76.0	42.0	84.0
Thomasville, N. C.	33.0	49.5	41.0	70.0	41.0	78.0
Roanoke, Va.	23.0	28.5	28.0	36.5	25.0	42.5
Winchester, Va.	40.0	34.5	25.0	31.5	36.0	36.5
Charleston, W. Va.	21.0	—	28.0	—	21.0	—

Source: Rail rates: Transportation and Storage Services Division, Commodity Stabilization Service, U. S. Department of Agriculture. Truck rates: Motor Tariff Bureau of West Virginia, Inc.

Table 56.—*Estimated truck and rail freight rates for paper (wrapping) from selected locations in West Virginia to major market centers*

(In cents/100 pounds)

Destination	Origin			
	Beckley		Parkersburg	
	Truck	Rail	Truck	Rail
New York, N. Y.	94.0	61.5	96.0	62.5
Philadelphia, Pa.	86.0	57.5	86.0	58.5
Pittsburgh, Pa.	82.0	51.5	49.0	30.5
Washington, D. C.	72.0	41.5	90.0	47.5
Cincinnati, Ohio	85.0	41.5	56.0	33.5
Cleveland, Ohio	95.0	41.5	56.0	33.5

Source: Rail rates: Transportation and Storage Services Division, Commodity Stabilization Service, U. S. Department of Agriculture. Truck rates: Motor Tariff Bureau of West Virginia, Inc.

Table 57.—*Estimated truck and rail freight rates for furniture from selected locations in West Virginia to major market centers*

(In cents/100 pounds)

Destination	Origin							
	Beckley		Elkins		Huntington		Richwood	
	Truck	Rail	Truck	Rail	Truck	Rail	Truck	Rail
New York, N. Y.	222	127	192	111	236	—	222	127
Philadelphia, Pa.	202	117	175	102	218	—	206	117
Pittsburgh, Pa.	184	106	137	80	149	—	155	87
Washington, D. C.	170	99	159	87	192	—	192	104
Cincinnati, Ohio	158	92	174	102	116	—	179	104
Cleveland, Ohio	179	104	158	92	145	—	170	99

Source: Rail rates: Transportation and Storage Service Division, Commodity Stabilization Service, U. S. Department of Agriculture. Truck rates: Motor Tariff Bureau of West Virginia, Inc.

Table 58.—*Number of unemployed male industrial workers by education and age classes, for selected locations in West Virginia*

Location and age class	Educational level		
	6th grade and under	7-11 grades	12th grade and over
Beckley:			
Under 45	328	1,548	547
45 and over	672	782	116
Total	1,000	2,330	663
Elkins:			
Under 45	27	149	77
45 and over	56	149	29
Total	83	298	106
Huntington:			
Under 45	140	839	439
45 and over	191	368	71
Total	331	1,207	510
Parkersburg:			
Under 45	31	342	245
45 and over	53	170	36
Total	84	512	281
Richwood:			
Under 45	115	515	211
45 and over	153	242	39
Total	268	757	250

Source: West Virginia Labor Force Bulletins, West Virginia Department of Employment Security.

Table 59.—*Number of unemployed male industrial workers by skill and age classes, for selected locations in West Virginia*

Location and age class	Skill class		
	Skilled	Semiskilled	Unskilled
Beckley:			
Under 45	463	724	1,236
45 to 64	511	368	689
Total	974	1,092	1,925
Elkins:			
Under 45	74	59	120
45 to 64	109	55	70
Total	183	114	190
Huntington:			
Under 45	400	397	621
45 to 64	286	152	192
Total	686	549	813
Parkersburg:			
Under 45	146	173	299
45 to 64	142	58	59
Total	288	231	358
Richwood:			
Under 45	235	214	389
45 to 64	186	99	148
Total	421	313	537

Source: West Virginia Labor Force Bulletins, West Virginia Department of Employment Security.

Table 60.—*Average hourly wage rates and ranges by skill class for the lumber and particle-board industries in selected locations in West Virginia*

(In dollars/hours)

Location	Skill class		
	Skilled	Semiskilled	Unskilled
Beckley:			
Average	1.80	1.50	1.35
Range	1.70-2.00	1.30-1.50	1.25-1.35
Elkins:			
Average	1.80	1.45	1.30
Range	1.70-2.10	1.30-1.55	1.25-1.35
Huntington:			
Average	1.85	1.55	1.40
Range	1.45-2.15	1.30-1.80	1.25-1.50
Richwood:			
Average	1.80	1.40	1.30
Range	1.65-2.00	1.35-1.50	1.25-1.40

Source: Estimates based on data obtained from the West Virginia Department of Labor and other sources in the State.

Table 61.—*Average hourly wage rates and ranges by skill classes for the woodpulp and furniture industries in selected locations in West Virginia*

(In dollars/hours)

Location	Skill class		
	Skilled	Semiskilled	Unskilled
Woodpulp:			
Average	3.50	2.75	1.75
Range	3.25-3.75	2.50-3.00	1.50-2.00
Furniture:[1]			
Average	1.90	1.50	1.30
Range	1.75-2.35	1.30-1.75	1.25-1.35

Source: Estimates based on data obtained from the West Virginia Department of Labor.

[1] Based on data for Huntington area. Hourly wage rates are estimated to be 10 percent higher for the Richwood and Beckley areas and 5 percent higher for the Elkins area to allow for higher training costs likely to be incurred in these areas.

Table 62.—*Ad valorem property tax rates in selected years for selected locations in West Virginia*

(In cents/$100 of assessed value)

Location	1960	1961	1962	1963
Beckley:				
Raleigh County	296.40	294.00	265.00	263.52
Summers County	181.40	190.00	190.00	190.00
Elkins:				
Randolph County	165.80	165.92	165.60	166.00
Huntington:				
Cabell County	209.64	209.64	209.64	209.64
Wayne County	241.80	241.80	241.80	241.80
Parkersburg:				
Wood County	291.80	288.20	286.20	282.80
Richwood:				
Nicholas County	190.00	190.00	190.00	190.00
Greenbrier County	195.90	150.00	150.00	150.00

Source: Twenty-eighth and twenty-ninth biennial reports of the Tax Commissioner of West Virginia.

Table 63.—*Estimated electricity rates for selected industries and locations in West Virginia*

(In cents/kilowatt-hour)

Industry	Beckley and Huntington	Elkins, Parkersburg, and Richwood
Lumber	[1]1.60	[2]2.20
Particle-board	[3]1.17	[4]1.06
Woodpulp	[5]1.10	[5] .90
Furniture	[1]1.66	[2]2.16

[1] Estimates by Appalachian Power Company, Charleston, W. Va., based on Rate Schedule CP.

[2] Estimate by Monongahela Power Company, Fairmont, W. Va., based on Rate Schedule C.

[3] Estimate by Appalachian Power Company, Charleston, W. Va., based on Rate Schedule CPO.

[4] Estimate by Monongahela Power Company, Fairmont, W. Va., based on Rate Schedule J.

[5] Estimates by author, based on published rate schedules for power companies serving the selected locations.

Table 64.—*Estimated cost/acre of industrial sites by industry, for selected locations in West Virginia*

Location	Industry	
	Lumber, particle-board, furniture	Woodpulp
Beckley	$400	$ 600
Elkins	400	—
Huntington	500	—
Parkersburg	500	1,000
Richwood	300	—

Source: Estimates by author, based on correspondence and discussions with industrial-promotion groups in West Virginia.

Table 65.—*Water characteristics for selected streams at selected locations in West Virginia*

Water characteristics	Beckley area		Parkersburg area	
	New River at Hinton	Greenbrier River at Alderson	Little Kanawha River at Parkersburg	Ohio River at Parkersburg
		DAILY DISCHARGE *cubic feet/second*		
Average	5,550	1,970	2,350	57,000
Maximum	232,000	77,500	46,300	440,000
Minimum	720	24	2	2,290
		ACIDITY *pH*		
Average	7.7	7.7	6.9	—
		TEMPERATURE *degrees F.*		
Average	60	56	68	—
Maximum	82	80	82	—
Minimum	39	33	32	—
		SUSPENDED MATTER *parts/million*		
Average	18	20	78	—
Maximum	44	49	250	—
		DISSOLVED OXYGEN *parts/million*		
Average	8.2	8.6	8.0	—
Minimum	7.0	7.7	6.0	—

Sources: U. S. Geological Survey. Surface Water Supply of the United States, 1957. U. S. Geol. Survey Water Supply Paper 1505, 553 pp., 1959.

Ferguson-Gates, Consulting Engineers. Stream and effluent data on the Greenbrier and New Rivers. Report prepared for the West Virginia Economic Development Agency. 8 pp.
West Virginia State Water Resources Commission. Stream sampling data (unpublished.)

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The PHOTO-CHOICE METHOD for Recreation Research

by Elwood L. Shafer, Jr.

U. S. FOREST SERVICE RESEARCH PAPER NE-29
1964

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

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The PHOTO-CHOICE METHOD for Recreation Research

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by Elwood L. Shafer, Jr.

The Question

WHAT do people want in forest-oriented outdoor recreation, and what are they willing to pay for it? This question is being asked constantly by those recreation planners and administrators who are striving to serve the public better.[1] We will probably never be able to determine preferences for all types of outdoor recreation facilities; this is so because the effects of certain population variables cannot be measured. However, there are areas in which scientific investigation of user preferences may prove useful — such as measuring preferences for park facilities and design, or measuring preferences for forest environmental conditions. It is in these areas of research that the photo-choice method may be an appropriate tool.

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[1] Resources for the Future. ANNUAL REPORT 1958: 41-57. Washington, D. C.

The Method

The photo-choice method of study described here was used in a study of outdoor recreation on four state parks in northeastern Pennsylvania in 1962. Only the method of study will be presented here. The results will appear in another paper now being prepared for publication.

This study was designed to measure a recreationist's preference among different types of outdoor facilities or conditions by means of several series of photographs. Each series of photos illustrated different types of a certain facility or condition.

For example, take picnic areas. The photo series might offer a choice among three different types of picnic areas: (1) a forest area having a high canopy, (2) an area with trees having a low canopy, or (3) an open parklike area with scattered trees (fig. 1). For a swimming area, the photo series might offer a choice of a sand-and-turf beach, a beach with trees, or a natural stream (fig. 2). Other photo series might illustrate different types of camping facilities, campsite spacings, sanitation facilities, or fireplaces.

Respondents, in personal interviews, were asked to designate the one type of facility within each series that they liked most — after considering an associated cost for each type. Cost figures represented a realistic use-cost for development, construction, maintenance, and expansion or replacement of individual facilities. If a respondent did not prefer any type of facility within any one series, he had the alternative choices of designating "none of these," or "not interested in this facility."

Photographs

Where possible, each photo series contained a photo of a high-, medium-, and low-cost item within a particular facility category. By covering the total range of costs for a facility, survey results reflected approximately, if not exactly, the preference patterns within any category. All photos within a series were taken about the same distance from the subject. For example, swimmers used for scale in figure 2 are all about the same size.

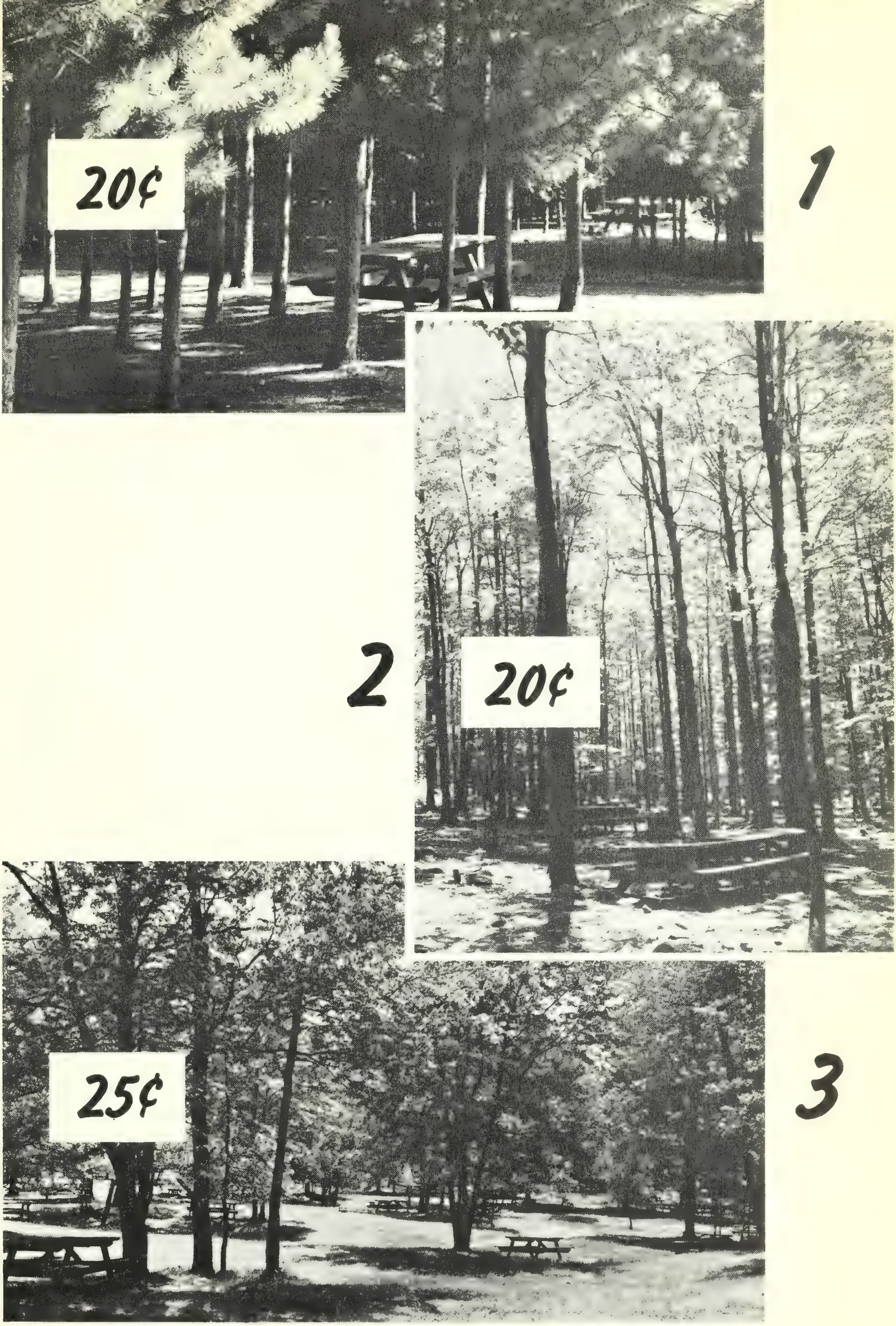

Figure 1.—Recreationists were asked: "Which picnic area would you choose? (1) Low canopy? (2) High canopy? (3) Scattered trees?"

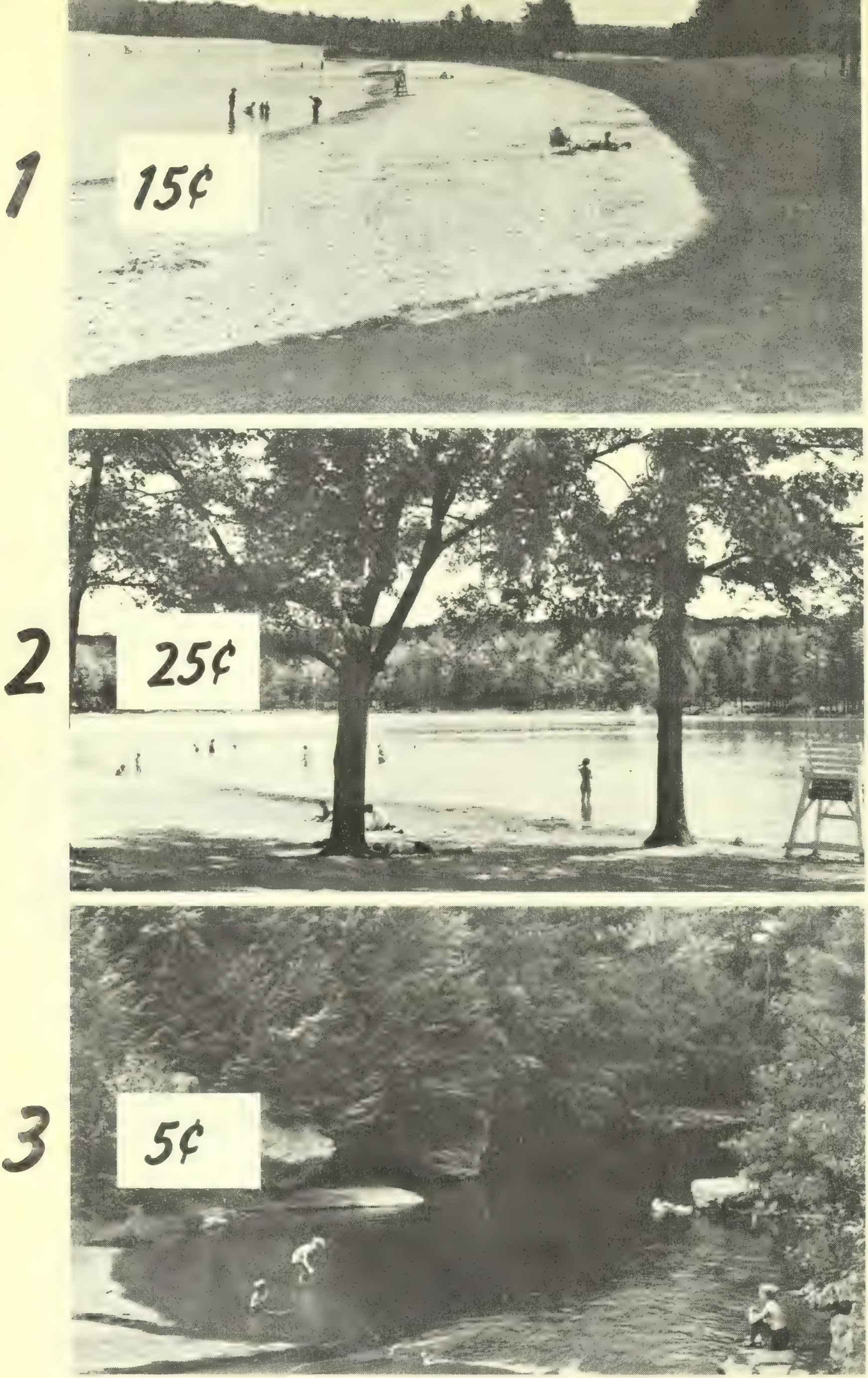

Figure 2.—Which swimming area would you choose? (1) Sand-and-turf beach? (2) Beach with trees? (3) Natural stream?

Costs

After deciding which facilities to illustrate in the survey, it was necessary to derive a user cost for each one. The procedure[2] used was as follows. First, the net present value of a facility cost (NPV cost) was computed. To do this, it was necessary to choose a relevant period of time over which the analysis would apply; this was about 20 years for most recreational facilities on state parks. After discussions with park managers and construction foremen, a schedule was prepared which included:

- The initial development costs of the facility.
- An annual listing of additional costs such as those for administration, maintenance, and replacement. These were discounted at compound interest (4 percent is suggested) to the beginning of the period.

This schedule allowed computation of the gross present value of costs (GPV cost). From this were subtracted the present values of any improvements not exhausted at the end of the period (as a simplification, a straight-line depreciation may be used). The result is the NPV cost. Finally, the use charge to cover NPV cost was determined by making —

$$\text{NPV cost} = \text{NPV returns}$$

and —

$$\text{NPV costs} = \frac{CN\ [1.0p^{n} - 1]}{(0.0p)\ (1.0p)^{n}}$$

where —

C = unit charge per day for a particular facility.

N = average number of times the facility is used per year — as computed from recent park attendance records.

^{n} = number of years in the analysis period.

p = interest rate (4%).

NPV costs = net present value of costs.

---

[2] As recommended by Robert Marty, forest economist, Northeastern Forest Experiment Station, Upper Darby, Pa.

So —

$$C = \frac{\text{NPV costs } (0.0p)\ (1.0p)^{n}}{N\left[(1.0p)^{n} - 1\right]}$$

Presentation

For the interview presentation, each photo was standardized to 3½ x 4½ inches in size. The photos were mounted in a protective plastic cover, and were arranged opposite the questions pertaining to that facility (fig. 3). To avoid the possibility that position of photos might affect the frequency with which they are chosen, the pictures should not be arranged in a fixed cost sequence.

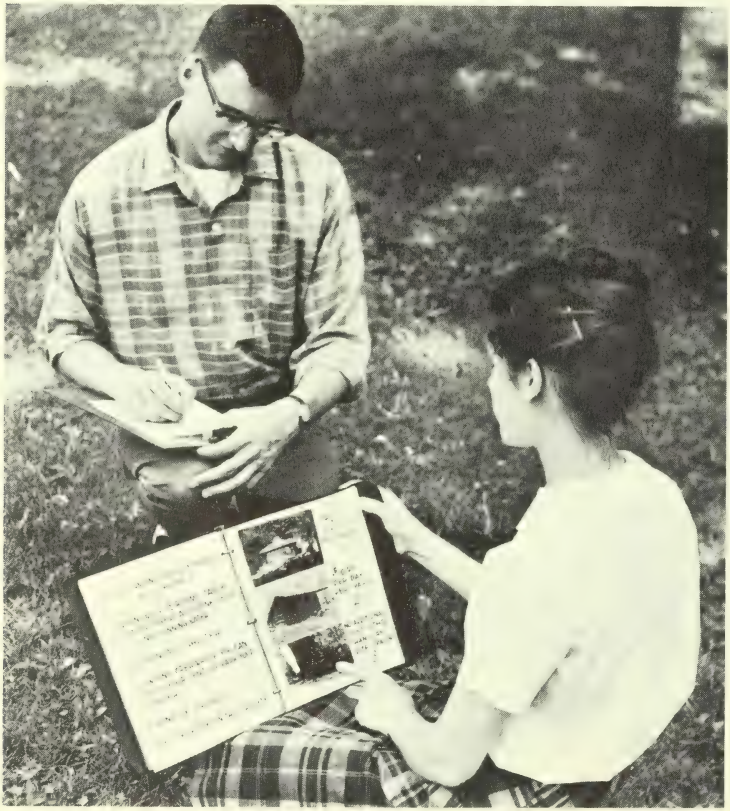

Figure 3.—In the presentation, the photographs were arranged opposite the questions pertaining to that facility.

The following refinements should be considered in the design of future photo-choice surveys:

- To determine the effect of costs in influencing choice, half of the respondents could be asked to select facilities from an interview presentation in which facility costs have been omitted.
- Several pictures of the same facility could be used to avoid bias due to content or picture quality. For example, the effect of rocks in the foreground of the high-canopy picnic area (fig. 1) might influence selection of this facility. The rocks were purely incidental to the photograph and not necessary to the general type of facility. One possible solution to this type of bias would be to use several photographs to indicate each general type of facility.
- Colored versus black and white photographs could be compared for differences in survey results.
- Respondents could be asked to rank their choices within each series. Resultant information might allow managers greater latitude in the decision-making process.

Interview Procedure

The most appropriate location for using the photo-choice method on public recreation areas was found to be at or near a swimming area. Observations by park supervisors indicate that, on a typical summer day, most of the people who come to a state park usually frequent the beach area and vicinity during their visit regardless of their other activities or the duration of their stay.

Sampling Design

Recreationists were sampled along a series of randomly selected parallel courses that ran perpendicular to the beach and extended into adjoining picnic areas (fig. 4). In traversing a course, the interviewer selected every n^{th} person to interview. Sampling ratios were determined from the previous year's park attendance records.

Each respondent selected was interviewed only once. An interview schedule that contained 6 series of photographs required 5 to 10 minutes per interview. When the interviewer completed a sampling course, he returned to the starting point and proceeded as before until the required number of people had been sampled for one day.

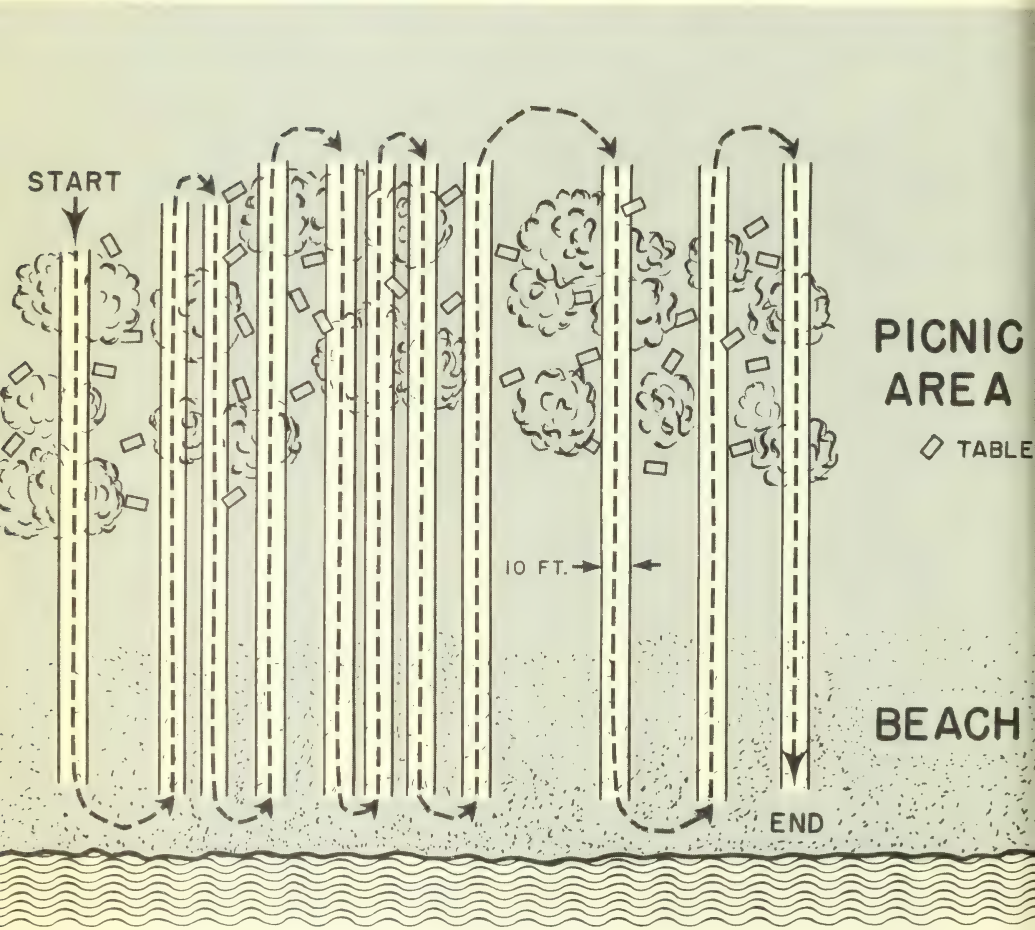

Figure 4.—Sketch of a sampling pattern for a photo-choice survey, showing the course followed by the interviewer.

Collection of Data

Interview periods were scheduled between 11 a.m. and 5 p.m., because during this time of day most recreational activity at a park is on or near the beach area. Interviews were restricted to typical summer days, and the interviewer asked the respondent to limit his choices to "a day just like today."

Before presenting the pictures to a recreationist, the interviewer explained to the respondent that:

- The cost of each facility selected would be added by the interviewer.
- The recreationist was to base his final combination of preferences for all facilities on the total cost per day of all items selected.
- After considering the total cost, the recreationist would be allowed to change his individual choices to coincide with a total cost that he would be willing to pay.
- When making his selections, the respondent should consider the type of group he is with on that day.

When the respondent objected or questioned the use of cost figures in influencing his selection, the interviewer explained that for this study some limitation has to be placed on the types of facilities so that everyone interviewed would be thinking along the same lines. In addition, the interviewer re-emphasized that these were actual costs and were considered as being paid directly by the user. Also, when necessary, a further explanation was provided by comparing this survey approach to a situation in which the recreationist might be asked which of two kinds of picnic lunches he preferred to have — a steak or a hot dog. Without a cost associated with this selection there was little doubt as to which one he would select. The interviewer then explained that this was the same reason for using a cost figure with the recreational facilities.

To insure proper interpretation of survey results, respondents were stratified as campers and noncampers; and campers were further stratified into those who were camping in the park at the time of the interview and those who were not.

Advantages and Limitations

The photo-choice survey method has several advantages:

- It is much faster than most procedures used to obtain this type of information.
- It is designed to be interesting to the respondent — this should help to establish rapport, decrease the number of nonrespondents, and encourage reliable answers.
- The pictures can be studied by the respondent without lengthy verbal instructions from the interviewer.

Several limitations of the method are:

- Answers to hypothetical questions of choice do not always indicate how people may act. That is, people may select one facility on the basis of photographs yet actually choose a different one when faced with the actual situation.
- Responses may be influenced by specific details in the pictures.
- The method does not measure real demand. Instead, it measures some degree of preference. But if this preference is consistent for certain facilities, then there will be some substance to the results and similar choices could be expected in other recreational situations.

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OAK SITE INDEX

on Belmont Limestone Soils in the Allegheny Mountains of West Virginia

■

by Harry W. Yawney

The Author

HARRY W. YAWNEY received his forestry training at the Pennsylvania State University, graduating with a Bachelor's degree in 1955 and a Master's degree in 1957. That year he joined the Northeastern Forest Experiment Station as a research forester and worked in timber-management research at Parsons, West Virginia, until 1962, when he was transferred to Burlington, Vermont, where he is currently doing research in seeding and planting with northern hardwoods.

OAK SITE INDEX

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in the Allegheny Mountains
of West Virginia

■

The Need to Predict Productive Capacity

THE productive capacity of forest land in the Allegheny Mountains of West Virginia often varies greatly by soil and topography from one area to another over relatively short distances. Gross differences in site quality are readily recognized on opposite slopes, and indeed differences can be seen to occur on the same slope. As forest land values continue to increase and management practices become more intensive, foresters and forest land managers are becoming more and more aware of the need to predict the productive capacity of the land.

Research scientists at the Northeastern Station, cognizant of the need, even 10 years ago, made a study in which the site index of several oak species was related by a regression equation to several topographic and soil factors for medium-textured, well-drained, upland soils in northeastern West Virginia (Trimble and Weitzman 1956). Their study was conducted on sandstone and shale soils—mainly Dekalb, Gilpin, and Calvin soil series; the obviously inferior shaly Ashby series and the superior limestone Belmont series were not included. These two soils were deliberately excluded from that study to minimize variations in soils that might affect tree growth and confound or obscure other variables important for predicting site productivity. Since publication of the Trimble and Weitzman study, additional site work has been done on the Belmont soil series.

The limestone soils in the Allegheny Mountain Region of West Virginia, though they occupy only about 5 percent of the forest land, are probably the most productive soils of the region. So a study was made to provide guidelines as a forest-management tool where these soils exist, and to gain a better understanding of the effect of limestone parent material on site productivity with respect to other parent materials in the same region.

Results of this follow-up investigation are presented in this paper, to relate the site index of red oak by regression equation to soil and topography. Also, oak site indexes on the Belmont soil series predicted by the equation given in this paper are compared with values predicted for the same plots by the equation developed by Trimble and Weitzman for the sandstone and shale soils.

Review of the Literature

Lutz and Chandler (1946) stated that, "In relatively small regions of uniform climate, the nature of the parent material is probably more important than any other single factor in determining the character and productivity of soils." In Sweden, Tamm and Wadman (1945) have suggested that, for areas of equal soil moisture, forest conditions can be correlated with type of bedrock.

In many site-evaluation studies made in the United States, it has been found that differences in productivity attributable to parent materials are not significant. Other soil factors such as texture, drainage, and depth of soil, along with topography, were usually more important. However, it is recognized that differences in parent material are often partly responsible for these observed soil and topographic differences. Some investigations have shown that parent material contributed to site-quality differences beyond those attributed to physical factors of the soil and topography. This situation seems to occur most frequently with calcareous soils.

Lutz and Chandler (1946) reported that, in the Southwest, soils derived from Permian limestones produced the heaviest and best stands of Ponderosa pine, provided precipitation was also favorable. In contrast to limestones, the Coconino sandstones produced both poorer soils and poorer timber. In the Lake States, Kittredge (1928) reported that the best growth of jack pine was found on soil types where a limestone formation was present or where limestone had been brought in by glacial action. Stoeckeler's study (1948) of aspen in the Lake States indicated that significantly better volume growth occurred on soils with a limy subsoil than on soils with an acid subsoil — although site indexes were practically identical and the physical properties were similar on both groups of soils.

In a recent comprehensive study of the physical and chemical properties of the soil, Stoeckeler (1960) found that the site-index advantage of aspen on soils with a lime-rich substratum was about 5 feet. Diebold (1935) considered the lime content of the entire profile to be of great importance in determining forest site quality. Soils developed from calcareous material of glacial origin were reported by Cox *et al.* (1960) to be among the best sites for growth of Ponderosa pine in western Montana; this was true where depth to the zone of calcium carbonate accumulation was greater than 4 feet. Where accumulation occurred at less than 4 feet, site indexes decreased as depth to lime decreased because of the high pH of the calcareous layers, which ranged from 8.0 to 8.5.

In the Black Hills, Myers and Van Duesen (1960) reported that, although the range of site index was the same, the average site index of Ponderosa pine was higher on limestone soils than on soils derived from other parent material. They explained this difference on the basis of more favorable growing conditions that existed on the limestone soils, such as less-steep slopes and deeper soils.

In Iowa, Einspahr and McComb (1951) found that a limestone soil (of the Sogn series) had the lowest oak site indexes of any of the soils investigated. However, these soils were located on exposed ridges and were extremely shallow; their reported average total depth was 8 inches. Eschner, working with the same soil series, reported similar results.[1]

Arend and Julander (1948), reporting on a study in the Arkansas Ozarks, concluded that "in general, the best growth of oak stands was measured on sites where the soils were derived from calcareous materials and the poorest on soils derived from sandstone and shale." They noted variations in site quality on all three soils and exceptions to the higher productivity of limestone soils, as follows: "Limestone soils also vary from unproductive, shallow, rocky soils low in water-holding ability to productive, deep, silty clay soils."

Lutz and Chandler (1946) stated:

> In general, limestone weathers rapidly, particularly the porous and impure varieties. The nature of the soil which develops from limestone depends to a considerable extent on the amount and kind of impurities contained, since the principal constituent, calcium carbonate, is dissolved and removed. In view of the great differences among limestones in kinds and amounts of impurities, it is not surprising that the derived soils are also extremely variable in quality. Soils derived from limestone are probably more variable than those derived from any other kind of rock (Ramann, 1905:100; Domes, 1938:473).

The Study Area

The study was made in Tucker and Randolph Counties in the Allegheny Mountains of West Virginia. Here the topography is rough, dominated by deep narrow valleys and sharp rising ridges.

Soils in these two counties are derived mostly from residual sandstones, shales, and — to a lesser extent — limestone. Most of the soils are medium-textured and well-drained, and total depth averages between 2½ and 3 feet.

Annual precipitation averages about 50 inches and is well distributed throughout the year, with snow contributing about 6 inches. Mean annual temperature is about 50°F., and length of the average frost-free growing season is approximately 140 days.

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[1] Eschner, A. R. GROWTH AND COMPOSITION OF OAK STANDS ON THE BRAYTON FOREST IN RELATION TO SOIL AND TOPGRAPHY. Unpublished master's thesis, Iowa State College, 1952.

The dry sites, which are generally the upper half of the south and west slopes and the narrow ridges, are dominated by chestnut oak *(Quercus prinus* L.), with these major associates: scarlet oak *(Q. coccinea* Muenchh.), white oak *(Q. alba* L.), black gum *(Nyssa sylvatica* Marsh.), sourwood *(Oxydendrum arboreum* [L.] DC.), and sassafras *(Sassafras albidum* [Nutt.] Nees). The lower half of the north and east slopes, and the coves, contain a rich mixture of yellow-poplar *(Liriodendron tulipifera* L.), sugar maple *(Acer saccharum* Marsh.), red oak *(Quercus rubra* L.), beech *(Fagus grandifolia* Ehrh.), white ash *(Fraxinus americana* L.), basswood *(Tilia americana* L.), black cherry *(Prunus serotina* Ehrh.), cucumber magnolia *(Magnolia acuminata* L.), and several other species of lesser importance. Between the extremes of the coves and the dry ridges a great variation in species composition occurs.

The Belmont Soil Series

The Belmont soil series, which dominates the limestone soils in the Allegheny Mountains, belongs to the Gray-Brown Podzolic group. The series occurs as upland soils developed from several beds of impure marine stone, which are separated by thin strata of alkaline red and gray shale, and sandstone. The Greenbrier stratum, the source of the parent material, ranges in thickness from about 150 feet to about 450 feet in Tucker and Randolph Counties. These strata are generally horizontal. They are bedded between the Mauch Chunk series above, which in turn are capped by the Pottsville series, and the Pocono series below.

The Belmont soils occur principally in bands along moderately steep to very steep hillsides. They are frequently influenced by colluvium from Mauch Chunk and Pottsville material. Due to the nature of the parent material and variable amounts of colluvium, Belmont soils vary considerably in depth, texture, color, content of coarse fragments, and reaction.

A representative profile description of the Belmont series is given as follows:

Horizon	*Depth (inches)*	*Description*
Aoo	3-0	—
Ao	—	Incorporated in A_1.
A_1	0-4	Dark Brown (7.5 YR 3/2) silt loam; moderate; medium granular structure; moist loose, pH 5.6; clear smooth boundary.
A_2	4-9	Dark brown (7.5 YR 4/2) silt loam; weak fine subangular blocky structure; moist friable; pH 5.6; gradual smooth boundary.
B_{21}	9-18	Dark brown (10 YR 4/3) silty clay loam; moderate medium subangular blocky structure; moist firm, slightly sticky and plastic when wet; pH 5.6; gradual boundary that tends to be irregular.
B_{22}	18-44	Dark brown (7.5 YR 4/4) silty clay loam; moderate to strong fine and medium subangular blocky structure; sticky and plastic when wet; pH 6.6 gradual smooth boundary.
C_1	44-51+	Dark brown (7.5 YR 4/4) clay loam to sandy clay loam; moist very friable; pH 6.8. Few coarse limestone boulders throughout profile.

Study Methods

The general plan of this study was, first, to test estimates of site index made according to the Trimble-Weitzman equation for sandstone-shale soils against site-index values determined from trees on the limestone Belmont soils; and then, depending on the outcome of this test, to develop a separate regression equation for oak site on the Belmont soils.

Field procedures were similar to those followed in the Trimble and Weitzman study (1956). On selected plots, sample trees were measured to determine height-over-age site index; and observations and measurements were recorded on factors of the soil and topography.

Data for the study were collected on 22 plots located in well-stocked, even-aged oak stands on medium-textured, well-drained Belmont soils. No definite plot size was used because plot stand-volume determinations were not a consideration. However, all sample trees were limited to areas of not more than 1/5 acre to insure fairly uniform soil and topographic conditions.

Tree heights and ages were determined for 5 to 10 dominant and co-dominant red oak trees on each plot. (Red oak was the sole species sampled except for one plot where white oak comprised 4 of the 8 trees sampled.) Total age was determined by adding 3 years to cores obtained at d.b.h. Tree site indexes were read from the site-index curves described by Schnur (1937). Average ages of the trees on the study plots ranged from 43 to 96 years, and the majority averaged about 50 years. Variation in sample-tree age on any plot was limited to 10 years, and plots with greater age spread were discarded.

Topographic variables included in the study were aspect, slope position, and slope percent. The methods of measuring these variables were as follows:

Aspect.—Orientation was measured with a hand compass, facing down the slope and across the plot.

Slope position.—Plot distance from the ridge was expressed as a percent of the total length of the slope.

Slope percent.—Steepness of the slope was measured in percent with an Abney level across the plot for a distance of approximately 2 chains.

Soil profile descriptions were written for 19 of the 22 plots from pits dug at the center of each plot.[2] Soils on the remaining 3 plots were carefully examined and verified by auger samples. In each of these three cases, limestone outcroppings were in evidence close by. The profile descriptions written followed the standard procedures used by the Soil Conservation Service. Soil samples were not collected for laboratory analysis. Soil texture was determined by feel at the pit. The LaMatte field kit was used for pH measurements. On each plot, average soil depth was determined with a soil depth probe (Yawney 1959) from measurements taken at five locations — at the plot center and at spacings of about 30 feet to either side and above and below the plot center. Maximum depth to which soil was measured was 3.5 feet.

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[2] Grateful acknowledgment is made for the cooperation of the Soil Conservation Service, U. S. Dept. of Agriculture. The help given by Woodrow Beverage, soil scientist of the Elkins, W. Va., office, who identified and described the Belmont soils in the field, is particularly appreciated. In addition, Mr. Beverage gave valuable assistance in interpreting the meaning of the soils data for this report.

When this study was begun, the plan was to investigate site-index relationships on more than 22 plots, but the difficulty of finding suitable stands containing oak on this soil limited the size of the study.

Results and Discussion

The results of this study indicate that the Belmont soils are highly productive, and that oak site indexes have a narrow range on these soils. Measured site indexes were comparatively high for each plot regardless of the combination of site factors involved (table 1).

An intensive search was made to cover the range of oak sites existing on these soils, but no plots were found with oak site indexes lower than 65 and none higher than 83. Better sites are known to exist, but it was not possible to find an adequate sample of oak trees on them. It appears that, as site conditions become more favorable, the oaks become a minor stand component or are completely absent from the species association.

On the basis of this study, oak sites on the Belmont soils could be classed by 10-foot site-index classes as either 70 or 80. In contrast to this narrow range, measured oak site indexes on the sandstone and shale soils within the same physiographic region ranged from a low of 35 or less to a high of 95.

Early in the study, it became apparent that estimates from the sandstone and shale equation (Trimble and Weitzman 1956) were not compatible with site indexes determined from trees on

Table 1.—Distribution of plots by dependent and independent variables for an oak site-index study on Belmont soils in West Virginia

Site index	Aspect			Slope position, in percent of distance from ridge to bottom of slope			
	NE	SE & NW	SW	0-20	21-50	51-80	81-100
70 (65-74)	—	3	4	1	2	3	2
80 (75-84)	4	7	4	3	—	10	1

Site index	Steepness of slope, in percent			Soil depth, in feet		
	0-20	21-50	51+	1.5-2.4	2.5-3.4	3.5+
70 (65-74)	—	3	5	—	3	5
80 (75-84)	1	8	5	1	8	5

the Belmont limestone soils. Preliminary analysis of the 22 plots, utilizing the "t" test with paired data, revealed that differences were significant beyond the 1-percent level. Site-index values from tree measurements were generally higher than the predicted values, though not uniformly so throughout the range. The comparison revealed disagreement to be greatest on the poorer sites, where differences ranged between 15 to 20 feet of site index. On the better sites, the Trimble-Weitzman equation provided estimates closely approximating measured site index.

Regression Equation for Belmont Soils

Because the sandstone-shale equation obviously did not apply to the Belmont soils, a separate regression equation was developed for oak site index on the Belmont soils.

In the previous site study by Trimble and Weitzman, oak site index was found to be highly correlated with certain readily measured soil and topographic factors; namely, aspect, slope position, slope percent, and soil depth. The effects of these same factors or independent variables on site index were determined for the Belmont soils. Nonlinear relationships of the independent variables were made linear with respect to site index by expressing:

1. Logarithm of site index to the base 10:

$$\mathbf{Y = \text{log site index}}$$

2. Aspect as the sine of the azimuth taken clockwise from southeast[3] and adding 1:

$$\mathbf{X_1 = \text{Sine (azimuth from SE)} + 1}$$

3. Slope position as the percent of distance from the ridge to the bottom of the slope:

$$\mathbf{X_2 = \text{Percent of distance from ridge line}}$$

4. Grade or steepness of slope as the slope percent:

$$\mathbf{X_3 = \text{Slope percent of the plot}}$$

5. Total soil depth to bedrock as the reciprocal of soil depth in feet:

$$X_4 = \frac{1}{\text{Soil depth in feet}}$$

The resulting equation is:

$$Y = 1.9792 - 0.0146\,X_1 + 0.0002\,X_2 - 0.0007\,X_3 - 0.1691\,X_4$$

The effects of several additional independent variables on site index were also investigated. These were pH of the A_1 and A_2 horizons; thickness of the A_1, A_2, and the total A horizons; and stand age. This was done by plotting residuals of site index over values of these independent variables. No relationships were evident.

R^2 for the regression is 0.503, and the regression is significant at the 5-percent level. The standard error is approximately 5-percent or about 4 feet for the average site index of 76 feet. And while only half of the variation for this regression is accounted for, the narrow range of sites on these soils permits good predictability with a small standard error.

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[3] Starting at the southeast puts the southwest aspect (which has the lowest site index) and northeast aspect (which has the highest site index) into their proper positions. Adding the plus 1 eliminates negative values.

The partial regression coefficients and the total correlation coefficients are compared in table 2 with values for the corresponding variables from Trimble and Weitzman (1956). None of the individual partial regression coefficients were significant at the 5-percent level (table 2), even though the multiple regression equation was significant. Of the total correlation coefficients (table 2) only two were significant: aspect and soil depth.

Based on the equation, site-index values were computed for ranges of the independent variables. These values are listed in table 3 for convenient reference.

Because the equation derived for the Belmont limestone soil has the same four variables as the Trimble-Weitzman equation for sandstone and shale soils, it was possible to determine quantitative differences in the potential productive capacities for oak between the two soil groups. Both equations were used to predict site-index values from the same topographic and soil-depth data measured on the 22 plots taken on the Belmont soil series. By superimposing the Trimble-Weitzman equation onto the Belmont

Table 2.—Regression and correlation coefficients for the variables on Belmont soils compared with values for corresponding variables on sandstone and shale soils

Variables	Limestone soils		Sandstone and shale soils[1]	
	Partial regression coefficients	Total correlation coefficients with Y	Partial regression coefficients	Total correlation coefficients with Y
Aspect	—0.0146	0.5068*	—0.0618**	0.5083**
Slope position	+ .0002	.0349	+ .0012**	.5299**
Slope percent	— .0007	.2264	— .0020**	.4038**
Soil depth	— .1691	.5661**	— .1509*	.4915**

*Significant at the 5-percent level.

**Significant at the 1-percent level.

[1] After G. R. Trimble, Jr., and Sidney Weitzman, 1956, Site Index Studies of Upland Oaks in the Northern Appalachians. Forest Sci. 2:162-173.

Table 3.—Site index of oak on Belmont soils as related to aspect, slope, and total soil depth in the Allegheny Mountains of West Virginia

Aspect	Soil depth (feet)	Slope percent							
		10	30	50	70	10	30	50	70
		TOP OF SLOPE *(1 percent distance from ridge)*				UPPER SLOPE *(33 percent distance from ridge)*			
SW (225°)	1.5	68	66	63	61	69	67	64	62
	2.5	75	73	70	68	76	74	71	69
	3.5	79	76	74	71	80	77	75	72
NW (315°) and SE (135°)	1.5	70	68	66	64	71	69	67	64
	2.5	78	75	73	71	79	76	74	72
	3.5	81	79	76	74	82	80	77	75
NE (45°)	1.5	72	70	68	66	73	71	69	67
	2.5	80	78	75	73	82	79	76	74
	3.5	84	81	79	76	85	83	80	77
		LOWER SLOPE *(66 percent distance from ridge)*				BOTTOM OF SLOPE *(99 percent distance from ridge)*			
SW (225°)	1.5	70	68	65	63	71	69	66	64
	2.5	77	75	73	70	79	76	74	71
	3.5	81	78	76	73	82	80	77	75
NW (315°) and SE (135°)	1.5	72	70	68	65	73	71	69	66
	2.5	80	77	75	73	81	79	76	74
	3.5	84	81	78	76	85	82	80	77
NE (45°)	1.5	75	72	70	68	76	73	71	69
	2.5	83	80	78	75	84	81	79	76
	3.5	87	84	81	79	88	85	82	80

soil plots, the site-index values thus calculated provided estimates applicable to other soils derived from sandstone and shale having the same topographic and soil-depth situations. Therefore, differences between the two estimates of site indexes reflect the inherent differences in the productive potential of the two soil groups.

Superiority of the limestone soil series over the sandstone and shale soils is illustrated by the regression line in figure 1. The points shown are the predicted site-index values calculated by both equations. A correlation coefficient of 0.883 resulted. Estimated mean site indexes for the 22 plots were 76 for the limestone soils and 64 for the sandstone and shale soils. The difference between the means was significant beyond the 1-percent level.

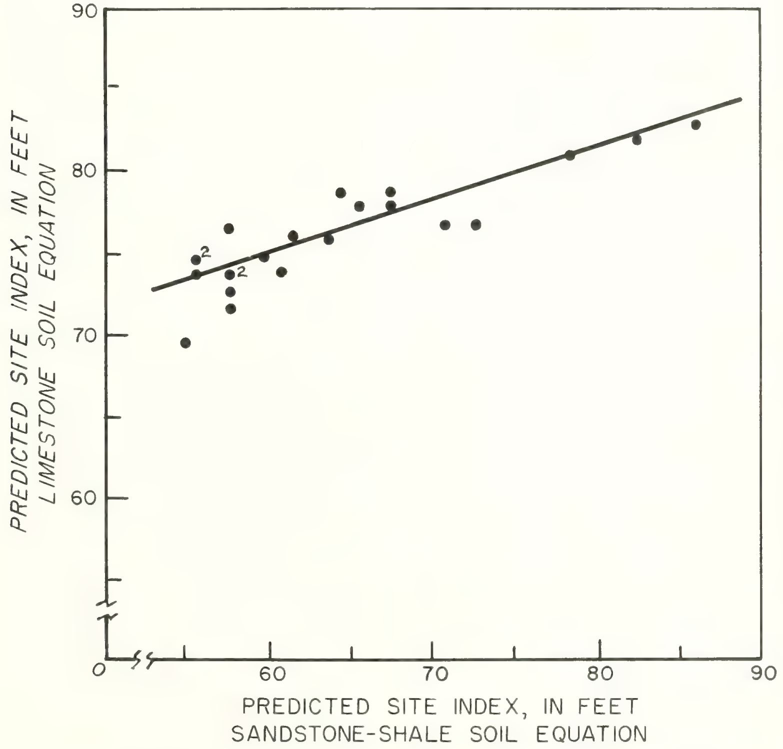

Figure 1.—Predicted oak site indexes on 22 plots of the Belmont limestone soil series compared with site indexes for sandstone and shale soils in the Allegheny Mountains of West Virginia.

The nature of the quantitative differences in the productive capacities of both soil groups for oak, as indicated by the two equations, is shown by examining the extremes in the ranges of predicted site indexes. For example, where the Belmont limestone soil equation estimates an oak site index of 73, the sandstone and shale equation indicates a site index of 55. Both equations predict approximately the same values around site index 83. Beyond this point, the trend shown by the comparison in figure 1 suggests superiority of the sandstone and shale soils. However, relationships beyond the data shown are unknown because of the absence of oak sample trees on the more productive Belmont soils.

Additional Information from Soil Surveys

Though soil samples were not collected for testing in this study, nor in the previous study by Trimble and Weitzman, recent intensive soil surveys in this mountain section by soil scientists of the U.S. Soil Conservation Service (1959) provide additional information on the soils in question.

The survey shows that Belmont silt loams have a higher clay content, particularly in the lower horizons, than the loams and silt loams of the Dekalb, Gilpin, and Calvin series, which were the predominant soils studied by Trimble and Weitzman (1956). The higher clay content indicated a greater water-holding capacity in the Belmont loams and perhaps more available moisture for tree growth. The textural difference may be the reason why Belmont soils have a higher site index in dry, topographic locations —such as upper slopes and southwest aspects—but have comparable site indexes in moist situations such as lower northeast slope.

The Belmont soils have a higher reaction. Though the range is wide within this series, the B_2 horizon averages about pH 6.5. In the sandstone and shale group the B_2 horizon averages about pH 4.6.

Soil structure is generally more favorable for plant growth in the Belmont soils. The Belmont soils have moderate to strong, fine, subangular, blocky structure in the B horizon. The Calvin and

Gilpin soils have weak to moderately strong, fine, subangular, blocky structure. And the Dekalb soil has weak, fine, subangular, blocky structure.

Percent base saturation for the Belmont soil is about 10 times greater than for soils from sandstone and shale. Of the total bases, calcium accounts primarily for these differences. As early as 1892, Hilgard (1892) observed that soils having a relatively high capacity to supply calcium are generally better forest sites than those having little available calcium.

Summary

An oak site-index study was made of the limestone-derived Belmont soil series in the Allegheny Mountains of northern West Virginia to determine and define the effect of easily measured topographic and soil factors on oak site index.

Field procedures on the 22 study plots used consisted of: (1) measuring site index by the standard height-age relationships; (2) making topographic measurements of aspect, steepness of the slope, and position on the slope; and (3) observing profile depths and horizon characteristics in soil pits. Standard Soil Conservation Service profile descriptions were made. Soil samples were not collected for laboratory analysis.

The results of the study indicate that the Belmont soils are highly productive for all of the natural combinations of topographic features and soil depth observed. However, to some extent observations were limited because oak sample trees were absent on the best Belmont sites. Oak was found to occupy an extremely narrow site range: site indexes measured on the 22 study plots fell between 63 and 83.

A prediction equation was developed for site index. The equation was based on the independent variables of aspect, slope position, slope percent, and soil depth. R^2 for the regression was 0.503, with significance at the 5-percent level. The standard error of estimate was approximately 5 percent, or about 4 feet at the average site index of 76 feet.

Differences were determined between oak site indexes on the

Belmont soils and on the shale and sandstone soils in the area for similar combinations of soil depth and topographic conditions. In the more adverse topographic locations, the Belmont soils had consistently higher site indexes. In the favorable topographic locations where the sandstone and shale soils had high site indexes, site differences between the Belmont and the sandstone-shale soils were negligible.

■

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Improvement in Butt-Log Grade *with increase in tree size, for six hardwood species*

by George R. Trimble, Jr.

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Improvement in Butt-Log Grade with increase in tree size, for six hardwood species

THE EVALUATION OF TIMBER QUALITY

MOST people who are concerned with the management of hardwood stands or the utilization of hardwood logs are aware that the quality of hardwood lumber is positively related to the size of the log from which it is sawed. Sawmill studies have frequently demonstrated that the larger logs yield a higher proportion in valuable lumber grades than the smaller logs. This is elementary; and if log size were the only criterion of potential lumber grade, estimating log value would be a simple procedure.

However, the proportion of quality lumber in a hardwood log is also affected by factors such as the number, size, and distribution of knots; the amount and distribution of rot or other interior defect; and the degree of log crook or sweep. These factors tend to vary among species.

When the basis for judging hardwood lumber grades is examined, it is readily apparent why defects — as well as log size — affect lumber grade. The following statement by Ostrander *et al.*[1] sums up the criteria for judging hardwood lumber quality:

> High-grade boards are those that will yield high percentages of clear face cuttings and relatively large individual cuttings. Low-grade boards are those that yield small percentages of clear face and sound cuttings.

Therefore, to evaluate the potential lumber-grade output of a log, we need a method of accounting for not only the effect of log size but also the effects of other important factors. Such a system of log grading has been developed through years of study by the U. S. Forest Service.[2] Visible surface characteristics of logs have been related to the proportions of high-, medium-, and low-grade lumber that the log will yield. The system establishes three grades (1, 2, and 3) for factory-lumber logs — logs that are suitable for conversion into standard factory lumber. Identification of the grade of the log is based on the same criteria for all species, with some exceptions.[3] But the percentages of the different lumber grades sawed out of logs of the same log grade are not the same for all species. For example — comparing the species that differ most — grade 1 logs of white ash yield an average of 80 percent No. 1 common and better lumber while grade 1 logs of chestnut oak and hickory yield only about 65 percent No. 1 common and better.[2]

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[1] Ostrander, M. D., *et al.* A GUIDE TO HARDWOOD LOG GRADING. U. S. Forest Serv. Northeast. Forest Expt. Sta., 50 pp., illus., 1963.

It is also generally — but not always — true that larger logs of the same grade yield a somewhat higher proportion of better grade lumber than smaller ones. However, differences in lumber quality due to increasing log size within a grade are less than differences between grades

Logs that fail to meet the minimum requirements of the factory lumber-log class may be placed in other categories, depending upon species and local markets. Two such classes are construction logs and local-use logs. Construction logs are sound logs that are suitable for high-quality ties and timbers but contain too many small sound knots to qualify as factory-lumber logs. Their value is generally less than that of high-grade factory logs; but for oak and certain other dense hardwoods, under some market conditions their value may be greater than that of grade-3 factory-lumber logs.

Local-use logs are those that fail to meet either factory or construction class specifications but still meet the minimum requirements that economically permit utilization — the *poorest log* concept. They contain unsound material or knots too large to qualify for construction logs and fail to meet the clear-cutting requirements of the grade-3 factory-lumber log.

Several publications have shown how log grades are applied in practice. Among the more complete of these reports are a recent one by Ostrander *et al.*[1] and one by Lockard, Putnam, and Carpenter.[4]

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[2] United States Forest Products Laboratory. HARDWOOD LOG GRADES FOR STANDARD LUMBER. U. S. Forest Prod. Lab. Rpt. D 1737, 66 pp., illus., 1953.

[3] Ash and basswood butt logs can in some cases be grade 1 logs at slightly smaller scaling diameters than other species. And special rules for grading black cherry logs, as yet unpublished, accept the presence of bud clusters and appreciable bark distortion without prescribing log degrade.

This log-grading system for evaluating timber quality is gaining acceptance in the hardwood regions. Also, there is a greater recognition among forest managers that managing for quality is essential to profitable hardwood forestry.

As an illustration of the differences in stumpage value among log grades, we can compare the computed stumpage value of 18-inch sugar maple logs:[5]

Log grade	*Stumpage value per M bd. ft.*
1	$79
2	$40
3	$ 6

This provides a ratio among stumpage prices for grades 1, 2, and 3 of approximately 13:7:1, respectively. Although the ratio varies somewhat among species and by log sizes, the general trend holds for all situations.

Examples of the kinds of situations where quality should be considered are:

1. Judging the suitability of a stand of timber for the product that management wants.
2. Determining the tree size that denotes financial maturity.
3. Setting of rotation age.
4. Setting cutting diameters in diameter-limit operations.
5. Appraising stumpage value by buyer or seller. If tree diameter could be related in general to log grade, such a relationship would be extremely useful as an aid in making the abovementioned decisions.

Work carried out by the Northeastern Forest Experiment Station in West Virginia in the past 12 years provides useful information about the relationships between tree d.b.h. and butt-log grade. The upper logs are not included in the relationships. Being smaller and containing more knots, these upper logs are generally of lower grade than the butt logs.[6] Thus the average grade of all material in the sawlog portion of the tree is generally lower than the average grade of the butt log.

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[4] Lockard, C. R., J. A. Putnam, and R. D. Carpenter. GRADE DEFECTS IN HARDWOOD TIMBER AND LOGS. U. S. Dept. Agr. Handbook 244, 39 pp., illus., 1963.

[5] From a Monongahela National Forest (West Virginia) stumpage appraisal made in 1962 and based on current lumber prices, current costs of production, and with appropriate allowance for profit and risk.

[6] Campbell, Robert A. TREE GRADES, YIELDS, AND VALUES FOR SOME APPALACHIAN HARDWOODS. U. S. Forest Serv. Southeast. Forest Expt. Sta., Sta. Paper 9, 26 pp., illus., 1951.

In the West Virginia data, species differences in d.b.h.-grade relationship are readily apparent. This inherent tendency for species to have different proportions of the various grades in logs of the same size is a familiar phenomenon to grade-conscious foresters who work with hardwoods. The results in this paper provide a quantitative evaluation of this tendency for six of the local species.

HARDWOOD STANDARD-LUMBER LOGS

*Grade Factors**		*Specifications*							
		Log grade 1			*Log grade 2*				*Log grade 3*
Position in tree		Butts only	Butts & uppers		Butts & uppers				Butts & uppers
Minimum diameter (inches)		[1] 13-15	16-19	20+	[2] 11	12+			8+
Minimum length (feet)		10+	10+	10+	10+	8-9	10-11	12+	8+
Clear** cuttings on each of the 3 best faces	Min. length (feet)	7	5	3	3	3	3	3	2
	Max. number	2	2	2	2	2	2	3	—
	Min. yield face length	5/6	5/6	5/6	2/3	3/4	2/3	2/3	1/2
Max. sweep and crook allowance; % of gross vol.		15			30				50
Max. cull and sweep allowance; % of gross vol.		[3] 40			[4] 50				50

*End defects, although not visible in standing trees, are important in grading cut logs. Instructions for dealing with this factor are contained in U.S. Forest Prod. Lab. Rpt. D1737.

**A clear cutting is a portion of a face free of defects, extending the width of the face. A face is one-fourth the surface of the log as divided lengthwise.

[1] Ash and basswood butts can be 12 inches if otherwise meeting the requirements for small No. 1's.

[2] 10-inch logs of all species can be No. 2 if otherwise meeting the requirements for small No. 1's.

[3] Otherwise No. 1 logs with 41-50 percent cull can be No. 2.

[4] Otherwise No. 2 logs with 51-60 percent cull can be No. 3.

Figure 1.—Hardwood factory-lumber log-grade specifications.

STUDY PROCEDURE

The trees graded in this study were taken at random in uncut second-growth hardwood stands in West Virginia. Most of the samples came from the Fernow Experimental Forest near Parsons, where the grading was done primarily to make initial timber-quality estimates on areas selected for testing different timber-management systems. About 20 percent of all the sample trees in this grading study were from oak site study plots distributed around the State.

In grading the butt log, the best 12-foot section of the first 16-foot log was graded — a standard practice in this region. The grading face (1/4 of the circumference), or the face that determined the grade of the log, was the next-to-poorest face; this also is standard practice.

The work was done by a number of men over a period of 12 years. All of the graders were trained and experienced in log-grading. The same grading rules were used throughout the study. The work was facilitated by the use of a field guide for grading, a condensation of grading instructions used in card form (fig. 1). (For more detailed instructions refer to the paper by Ostrander *et al.*)

Four log grades were used in computing the d.b.h.-butt log grade relationship: factory grades 1, 2, and 3 and the construction-log grade. Cull butt logs, and butt logs classified as local-use logs because of extreme roughness and rot, were disregarded. It was felt that because these poorer grades usually resulted from incidents of past history, they were not representative of the inherent grade tendencies of the species. The use of such logs — although they are common in some stands — might have distorted the comparisons among species of d.b.h.-grade relationship.

RESULTS

Butt-log grades have been related to tree size for the following species:

	Trees graded (No.)
Sugar maple (*Acer saccharum* Marsh.)	223
Chestnut oak (*Quercus prinus* L.)	266
Red oak (*Quercus rubra* L.)	578
White oak (*Quercus alba* L.)	192
Yellow-poplar (*Liriodendron tulipifera* L.)	213
Beech (*Fagus grandifolia* Ehrh.)	195

All Factory-Log Grades

Although the definition of a minimum-size factory log is a log 8 feet long with a minimum diameter inside bark of 8 inches at the small end, many trees with logs of this size or larger will not produce a grade-3 (minimum grade) factory log because of imperfections.

The percentage of trees with factory-grade butt logs 1, 2, or 3 increases with tree size, although the rate of increase varies among species (fig. 2). For example, beech obviously contains a smaller proportion of factory-grade logs in most diameter classes than any other species, while most yellow-poplar butt logs are of factory grade even in the smallest sawtimber trees.

The final curves showing the relationships of butt-log grade to d.b.h. were constructed by first developing smooth curves for each species of the percentage of butt logs in each of the four log grades (1, 2, 3, and construction) over d.b.h. class. Then, the sheaf of curves for each species was adjusted so that the sum of the percentages for each d.b.h. class equalled 100 percent.

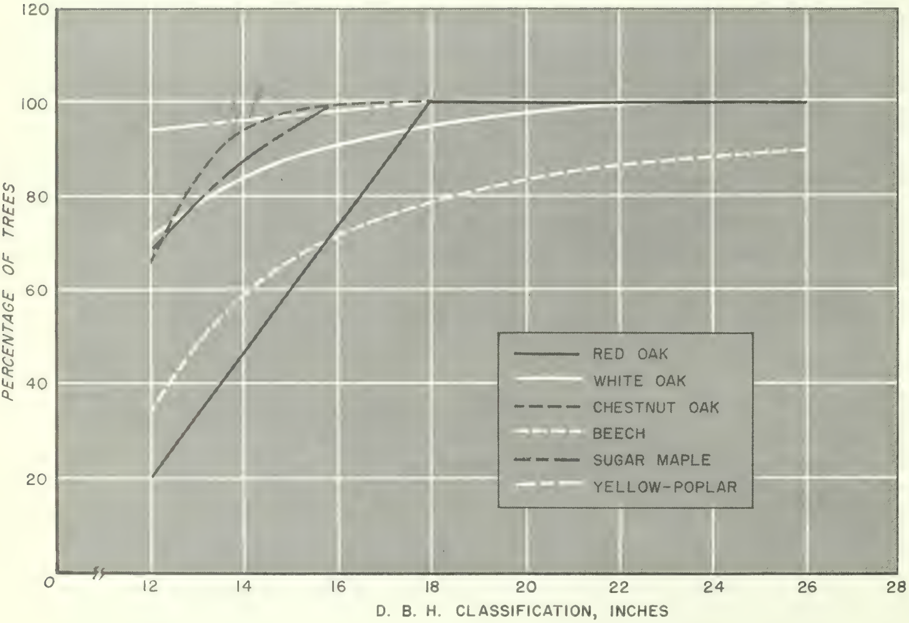
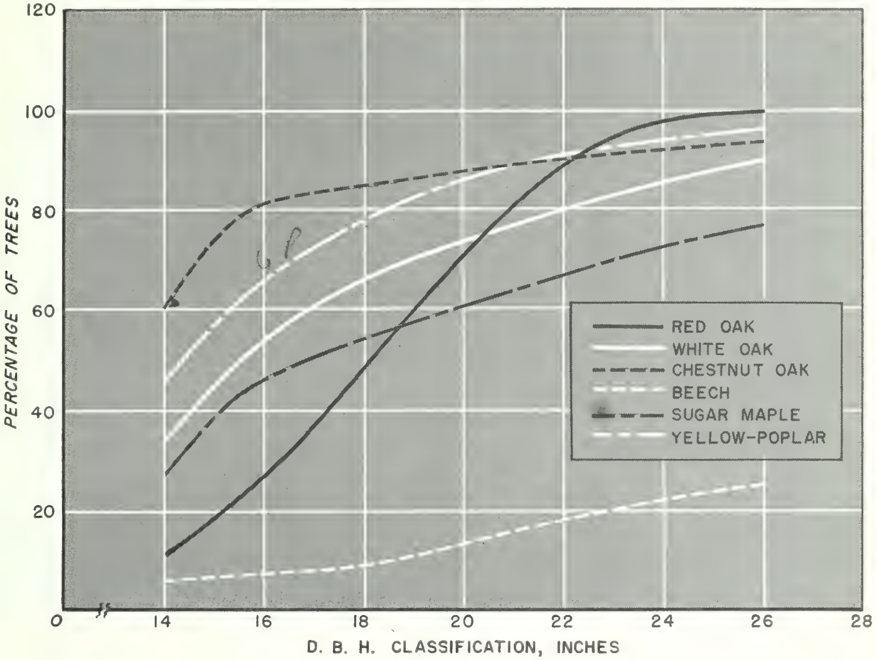


Figure 2.—Smoothed and adjusted curves of percentage of trees with butt logs in factory-lumber log grades 1, 2, or 3 over 2-inch d.b.h. class, for six hardwood species in West Virginia.

Figure 3.—Smoothed and adjusted curves of percentage of trees with butt logs in factory-lumber log grades 1 or 2 over 2-inch d.b.h. class, for six hardwood species in West Virginia.



Grade 1 and 2 Logs

The quality of lumber produced from grade-3 factory logs is generally low; and, except in the more valuable species, logging and milling these logs is often a marginal — sometimes a losing — business. For this reason, it is pertinent to look at the smoothed and adjusted curves of butt-log grade distribution over d.b.h. for factory grades 1 and 2 — the money-making grades. The percentage of trees with a grade 1 or 2 butt log is posively related to tree size (fig. 3).

Grade 1 Logs

Except for veneer logs, which were not considered in this study, the top grade is the grade-1 factory log. As shown previously, a grade-1 log of sugar maple has about twice the stumpage value of a grade-2 log. As with the trends for the preceding groups of log grades, results of the study reveal that the percentage of trees with a butt log grade of 1 increases with tree size (fig. 4).

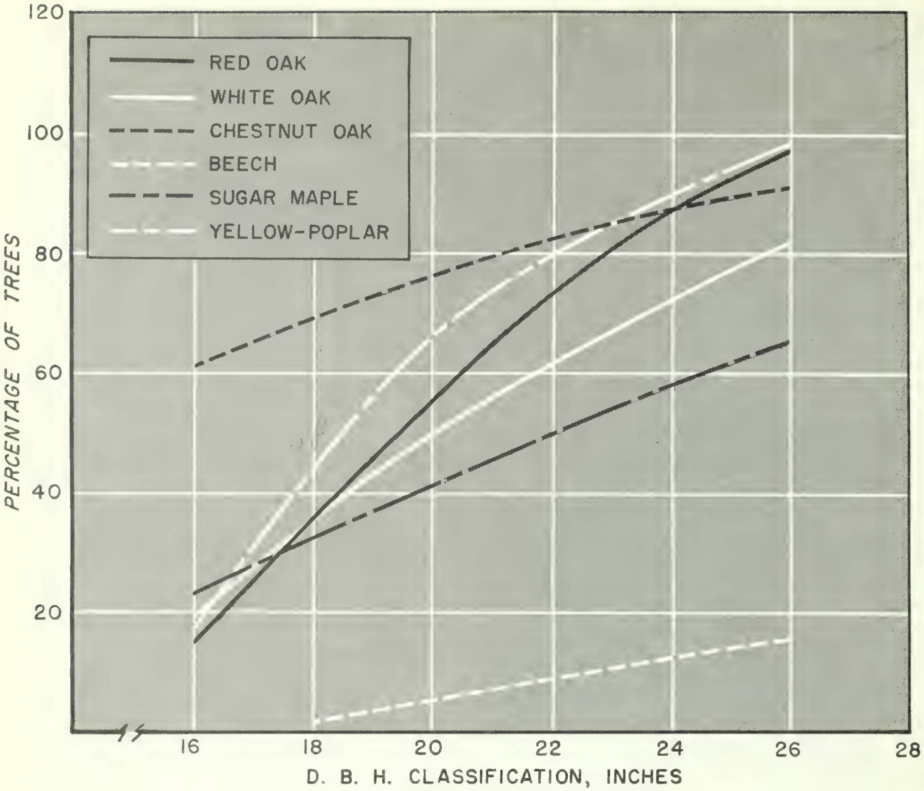


Figure 4.—Smoothed and adjusted curves of percentage of trees with butt logs in factory-lumber log grade 1 over 2-inch d.b.h. class, for six hardwood species in West Virginia.

ANALYSIS

Tests were made to detect significant differences between pairs of species in d.b.h.-grade relationship. Chi-square was used with the original or unadjusted data.

All Factory-Grade Logs

The first test involved the relationship between d.b.h. and the percentage of trees with factory-grade logs. The test was made for the range of d.b.h. classes where one of the two species being compared had less than 100 percent of the butt logs in factory grades. For example, yellow-poplar was compared to white oak in the 12-, 14-, 16-, and 18-inch d.b.h. classes and to chestnut oak in the 12-, 14-, and 16-inch d.b.h classes. As a result of testing, it was found that the following species differed significantly[7] from each other, except as noted, in the relationship of butt-log grade to d.b.h.:

	Exception (species below show no significant difference from the one to the left)
Yellow-poplar	Sugar maple and chestnut oak
Red oak	—
Beech	—
White oak	Sugar maple
Chestnut oak	Sugar maple and yellow-poplar
Sugar maple	Chestnut oak, yellow-poplar, and white oak

Grade 1 and 2 Logs

The same type of chi-square testing was continued to determine which species differed in d.b.h.-grade relationship for log grades 1 and 2. A wider diameter range could be compared here than in the analysis for all factory grades because of the less frequent occurrence of 100-percent or 0-percent observations. For example, chestnut oak and sugar maple curves for all factory grades combined coincided (at 100 percent) from d.b.h. class 16 upward (fig. 1), while the corresponding curves for grades 1 and 2 combined were separate across the observed range of d.b.h. classes above 12 inches (fig. 2). It was found that the following species differed significantly from all other species, except as noted, in the relationship of butt-log grade to d.b.h.:

	Exception (species below show no significant difference from the one to the left)
Yellow-poplar	Chestnut oak
Red oak	—
Beech	—
White oak	Sugar maple
Chestnut oak	Yellow-poplar
Sugar maple	White oak

Grade 1 Logs

The results of a comparable analysis of d.b.h.-grade relationships for grade-1 logs showed that each species differed significantly from all others, except as noted below, in relationship of butt-log grade to d.b.h. This analysis covered a slightly more restricted range of d.b.h. than the analysis for grades 1 and 2 combined because of the absence of grade-1 logs in the small d.b.h. classes:

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[7] A significant difference means that unless a 1-in-20 chance has occurred, there is a real difference between the species.

	Exception (species below show no significant difference from the one to the left)
Yellow-poplar	Red oak
Red oak	Yellow-poplar and white oak
Beech	—
White oak	Red oak and sugar maple
Chestnut oak	—
Sugar maple	White oak

DISCUSSION

A number of questions arise concerning the interpretation of the results of this study. Among the most important are: How valid are the data? What causes the differences among species? Exactly how can these results be applied in timber management?

How Valid Are the Data?

In judging the validity of the data, it is worthwhile to consider in detail how they were taken and to speculate about the nature and seriousness of possible sources of variation.

As mentioned previously, the data were taken over a restricted area, mostly on the Fernow Experimental Forest. The trees were in well-stocked stands on fair to excellent sites with site index 70 for oak probably most representative of the sample. Few trees from sites poorer than site index 55 for oak were included in the sample. The majority of the sampled forest stands were even-aged second growth containing scattered residuals left from the original cutting. The residuals represented species that were not in much demand when the virgin forests were cut. Of the six species in the study, yellow-poplar was represented by second-growth trees almost exclusively; red oak up to about 20 inches d.b.h. and chestnut oak up to about 18 inches d.b.h. were second growth; and white oak, beech, and sugar maple trees over 16 inches d.b.h. were mostly residuals from the original cuttings.

The stands sampled showed little or no evidence of past fire damage on the living trees. No cutting since the original harvest, except for the removal in some places of dead chestnut, was evident. There were no signs of current or past grazing by domestic stock.

The sampled trees were taken at random. The six species were sampled as they occurred in the stands. In many situations, the species grew in mixture. However, there was a correlation between site quality and relative frequency of occurrence of some species. For example, yellow-poplar was more common on the better sites and chestnut oak on the poorer sites.

The trees were graded by well-trained foresters who graded carefully with research standards in mind. The same grading rules were used throughout the period of study.

Surface indicators of degrading defects were relied upon because logs were graded in the standing tree and end defects could not be seen. It should be noted that, in areas where worm holes are prevalent in the chestnut and white oak — a common situation — the grade relationships as determined here are not valid for these two species unless the lumber is marketed under the terms, "worm holes no defect".

Within species and size classes, considerable variations in grade due to environmental differences among stands and to grader-judgment differences were possible: even well-trained men do not grade alike because they do not apply grading rules with the same judgment. However, conceivably the data used in this study are about as reliable as can be expected with a large sample embracing a range of species and d.b.h. classes. The consistency of the relationships and the results of the statistical analyses confirm to some extent the reliability of the data.

What Causes Differences Among Species?

The author believes that inherent differences in grade tendencies exist among species — primarily because of inherent differences in branching habit and frequency of dormant buds. It is readily acknowledged that degrading influences of the environment — such as fire, sapsuckers, logging injuries, and low site quality — may operate in many stands to distort inherited tendencies. However, considering the type of stands sampled, we think that most of these effects have probably been kept at a practicable minimum; any remaining variation due to environmental differences — and to grader-judgment differences also — may necessarily have to be accepted. An alternative might be to take a much smaller sample under even more uniform conditions. This might or might not give more usable results — if it could be done. It is also quite possible that more representative (and usable) results would have been obtained from a study that covered a wider range of conditions in the Appalachians.

It should be stressed that the grade characteristics of species as reflected by the study data are assumed to be independent of man's influence. A study like this cannot be made in stands under intensive management. For example, a number of areas under management on the Fernow Experimental Forest have been cut selectively once or twice. In these stands the present butt-log grades of the trees are much better for a given diameter class than is indicated by the relationships in this paper — because the trees of poorer grade (actual and potential) were cut in the managed areas. To illustrate, the few beech left in our managed stands after two cuts have average log grades far higher than those of the beech in the original stands. Some discussion of the more interesting grade relationships follows:

Chestnut oak.—The fact that this species grades relatively high may surprise many people. Two things should be kept in mind:

1. Chestnut oak usually yields relatively poorer lumber for a given log grade and diameter than most other species. One reason is that this species is particularly subject to worm attacks that degrade the lumber but usually do not leave detectable evidence of their presence on the log surface.
2. Chestnut oak from poor sites — dry ridges — was lightly represented in the sample. Because chestnut oak is such a prominent stand component on poor sites where most hardwood trees are of poor form and full of butt rot from past fires, this species is usually considered an undesirable tree. However, on fair sites or better, chestnut oak has good form and actually clears up faster than most other species.

Red oak.—The relatively low grade of this species at small diameters is due to the presence on the bark of numerous dormant buds. At least a portion of them are considered degrading imperfections. As the tree increases in d.b.h., the effect of these buds on log grade decreases, and large red oak grade up very well indeed.

The decreasing effect of buds on log grade as tree d.b.h. increases is due to several factors: (1) the grade rules call for classifying fewer buds as degraders in logs over 14 inches d.i.b. than in smaller logs; (2) as the log diameter increases, all defects become less important because shorter clear cuttings are permitted; and (3) apparently the actual number of buds may decrease with increasing tree size

Beech.—This tolerant, limby tree is notorious for its numerous surface imperfections and its low-grade logs. Well-formed, clean-stemmed beech trees are almost a rarity in the study area.

Yellow-poplar.—This intolerant species is well known for long clean stems, resulting from the early death and natural pruning of shaded branches. It frequently produces the maximum log grade for a given log size that is permitted by the grading rules. In the study area, one of the most frequently encountered grade defects was sapsucker damage.

APPLICATION OF RESULTS

The obvious general conclusion from the results of this study is that vigorous trees of high-grade potential should be reserved until they reach their peak of grade development — if the maximum production of quality lumber is desired.

Using figure 3 — the curves for log grades 1 and 2 — as a criterion, we see that until trees are 13 or 14 inches d.b.h. (or about 16 inches on the stump) they contain only small logs of marginal stumpage value. All species except beech show a rapid improvement in butt-log grade between 14 and 16 inches d.b.h. At about 16 inches d.b.h., chestnut oak grade improvement tapers off but the other species continue to improve rapidly in grade of the butt log until they are 18 inches d.b.h. or larger. This means that in an average or better stand of mixed Appalachian hardwoods, it probably would be extremely shortsighted to make a harvest cutting before the trees are 18 to 20 inches d.b.h. (about 22 to 25 inches on the stump). And when grade-1 logs (fig. 4) are considered, much can be gained by waiting until the trees are even larger.

A more precise interpretation of the meaning of these relationships will be possible when grade improvement of the upper logs is considered, when tree-growth rates are determined and applied, and when growth rates by tree-quality class are expressed as dollar values and interest rates. Employing these data, the forest manager will be working on a sounder basis for evaluating timber-management practices, setting rotations, discriminating among species, and marking trees to cut or leave. However, the current results on the relationship of butt-log grade to d.b.h. are still quite useful as guides to management and utilization, and several specific applications are given below:

Case 1

Question: A mill man is buying sugar maple stumpage to fill orders for high-quality lumber for furniture. He can sell only a small amount of low-grade lumber. He is offered a stand of timber that contains 100,000 board feet in trees 12 to 16 inches d.b.h. He must take all or none. Should he accept the offer?

Answer: *Definitely not. He needs grade-1 and grade-2 logs, particularly grade 1's. He will get relatively few grade-1 logs from this stand and, as a result, will saw out little high-grade material.*

Case 2

Question: A sawmill man has the chance to buy a stand of hardwood timber based on a diameter-limit cutting. He can sell all kinds of lumber but makes no money on grade-3 logs or poorer. He has a choice on this lot between cutting 5,000 board feet per acre to a 14-inch stump or 3,000 board feet per acre to an 18-inch stump. The price per 1,000 board feet is the same in each instance. Which cutting should he make?

Answer: *The latter. He probably would handle the extra 2,000 board feet at a loss if he took the first choice, unless he could buy the stumpage at a very low price.*

Case 3

Question: A man owns a stand of timber, which is on a good site and composed mostly of yellow-poplar, red oak, and sugar maple. There are 3,000 board feet per acre in old growth; and 8,000 board feet are in second growth between 11 and 18 inches d.b.h. and averaging 15 inches. How should the stand be marked?

Answer: *Mark the old residuals and those stems of second growth that are poor risks or have no grade-improvement potential. The owner cannot afford to sell good second growth at these sizes; few of the butt logs will be grade 1 — probably less than 15 percent (fig. 4). In another 10 years the trees will have grown an average of 2 to 3 inches in d.b.h., and probably about a third of them will have developed grade-1 butt logs.*

IMPLICATIONS FOR FUTURE RESEARCH

This study has produced information that can be used as a first step in determining average value growth rates for measuring economic maturity. To fulfill all the requirements, the following information is needed:

1. Upper-log grades by species, d.b.h. class, number of logs in the tree, and butt-log grade.
2. Diameter growth rates by species, d.b.h. class, site class, and a usable tree classification such as a dominance or vigor class.
3. Log values based on lumber values and costs of utilization.

Much of the needed field data have been obtained for West Virginia, and more are being collected. Within 1 to 2 years the necessary information should be available for the development of preliminary financial maturity guides.

Some other research needs in connection with the development of these guides are:

1. To increase the number of species for which data are being collected.
2. To study the effect of timber management on the relationship between log grade and tree characteristics.
3. To develop a method for predicting changes in tree grade or butt-log grade for individual trees.

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Regeneration of Birch

and associated hardwoods after patch cutting

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by David A. Marquis

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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DAVID A. MARQUIS received a Bachelor of Science degree in forestry from the Pennsylvania State University in 1955 and a Master's degree from Yale University in 1963. Since joining the staff of the Northeastern Forest Experiment Station in Laconia, New Hampshire, in 1957, he has studied problems of regeneration and thinning in northern hardwoods.

Regeneration of Birch

and associated hardwoods after patch cutting

■

IN 1958 a series of birch-regeneration studies was begun on the Bartlett Experimental Forest in New Hampshire. These studies have dealt with the environmental factors that affect birch regeneration—chiefly light exposure, soil moisture and soil temperature, and seedbed conditions. In brief, it has been found that germination of birch seeds is best under conditions of high soil moisture and moderate soil temperature. These conditions occur most often on mineral soil seedbeds and in locations shaded from direct sunlight. Height growth, however, is better on organic seedbeds and in direct sunlight *(3)*. To find out how important these and other factors are in actual practice, a survey was made of the amount, distribution, and size of reproduction in several 3-year-old patch cuttings.

Area and Methods

In August 1958, two series of patch cuttings were made. In the first area, known as compartment 45, 8 rectangular patches were cut, each measuring 4.0 by 1.7 chains (2/3 acre). Compartment 45 lies at an elevation of about 950 feet on a gentle northerly slope. The timber is primarily second-growth northern hardwoods dating from heavy cuttings 70 to 90 years ago. The other series consisted of 12 circular patches, varying in size from 0.1 to 0.3 acre, in an area known as compartment 31. This compartment lies at an elevation of 1,700 to 1,900 feet on a steep northerly slope. The timber here is typical old-growth northern hardwood, never having been heavily cut.

All merchantable material was cut and skidded in tree lengths from the patches, using an HD-5 tractor and arch. All other trees down to 2 inches d.b.h. were cut and left on the ground.

Seed crops in 1958 for the birches of major interest were rated as heavy for paper birch *(Betula papyrifera)* and medium for yellow birch *(B. alleghaniensis)*.

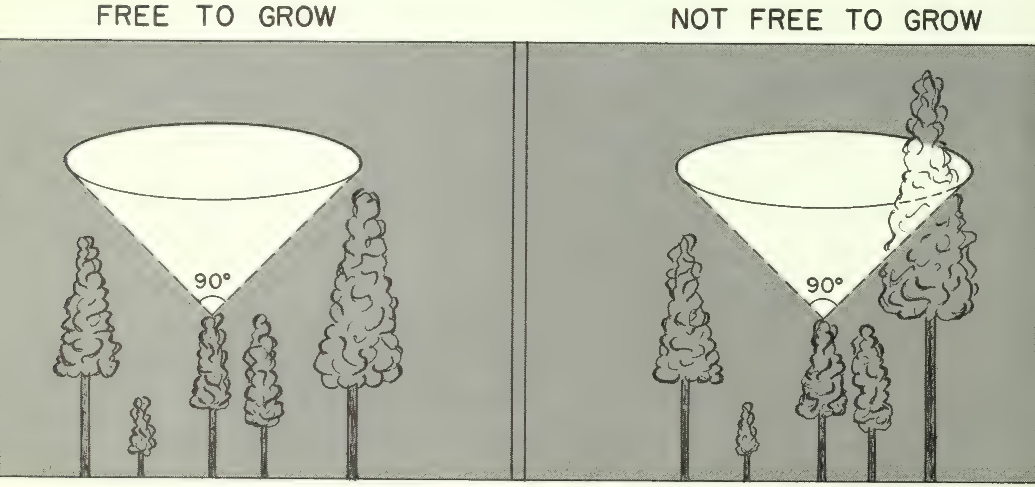

Figure 1.—An imaginary 90-degree cone was used to determine the classification of a tree as free-to-grow or not-free-to-grow.

A survey of the reproduction was made on both series of patches 3 years later, in the fall of 1961. Circular milacre plots were taken at 25-foot intervals on grid lines 25 feet apart. The starting point and direction of the first line in each patch, and the starting point on each line, were selected at random. Maps that had been drawn at the time of logging to show skidtrails, slash piles, and other pertinent features were used in conjunction with ground observations to classify seedbed conditions on each sample milacre. Four conditions were recognized:

1. **Skidroads:** skidroads and trails on which mineral soil had been exposed on at least 50 percent of the area.
2. **Disturbed:** areas disturbed by logging but with mineral soil exposed on less than 50 percent of the area.
3. **Undisturbed:** areas undisturbed by logging.
4. **Slash piles:** tree tops and slash in piles originally 4 feet or more high.

All reproduction on each milacre was tallied by species[1] and origin (seedlings, sprouts, or root suckers). Then the milacre was divided into quarters and the dominant (tallest) stem on each quarter was recorded by species, origin, height, and whether or not it was free to grow. If this stem was not a birch, the origin and height of the tallest birch were also recorded on that 1/4-milacre. A stem was considered free to grow if an imaginary inverted cone of 90° angle could be placed on its terminal and not intercept the foliage of another seedling or sprout (fig. 1). This arbitrary system worked well for identifying the stems that were tall enough in

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[1] SPECIES TALLIED

Common name	Scientific name
Paper birch	*Betula papyrifera* Marsh
Yellow birch	*Betula alleghaniensis* Britton
Sugar maple	*Acer saccharum* Marsh
Beech	*Fagus grandifolia* Ehrh.
Red maple	*Acer rubrum* L.
White ash	*Fraxinus americana* L.
Pin cherry	*Prunus pensylvanica* L.
	Prunus virginiana L.
Striped maple	*Acer pensylvanicum* L.
Raspberry	*Rubus* sp.
Others not included above	

relation to their neighbors to receive direct light. A total of 286 milacres was sampled.

Analysis of variance was used to test the significance of differences in stocking and height due to seedbed and compartment. Because an unequal number of milacres was sampled for each seedbed, the approximate method for computation of sums of squares with unequal frequencies was used *(4)*.

Results and Discussion

STOCKING

Regeneration was abundant in all patches: all space except the larger slash piles was stocked with some type of vegetation. Yellow and paper birch seedlings combined were more numerous than any other species: they made up nearly half of the total reproduction. Other merchantable species were also present. But in spite of their abundance, seedling stems of merchantable species were

Table 1.—Stocking in 3-year-old patch cuttings, by seedbed condition, in percent of 1/4-milacres stocked

Condition	Any woody species	Dominant merchantable species	Dominant merchantable species of seedling origin	Dominant birch	Free-to-grow birch	Any birch
COMPARTMENT 45						
Skidroad	100	12	9	10	9	97
Disturbed	100	5	3	1	3	96
Undisturbed	100	13	5	3	2	68
Slash	86	25	20	4	4	30
All seedbeds	98	14	8	4	4	67
COMPARTMENT 31						
Skidroad	100	39	22	18	35	91
Disturbed	100	37	22	5	12	95
Undisturbed	100	53	22	3	9	47
Slash	83	43	20	3	0	17
All seedbeds	99	46	22	9	16	60

Table 2.—Stocking in patch cuttings, by species and seedbed condition—all trees

Species	Skidroad		Disturbed		Undisturbed		Slashpile	
	M stems per acre	*(%)*	*M stems per acre*	*(%)*	*M stems per acre*	*(%)*	*M stems per acre*	*(%)*
			COMPARTMENT 45					
Paper birch	104.0	(37)	65.8	(37)	17.0	(13)	3.2	(6)
Yellow birch	63.0	(23)	14.8	(8)	9.7	(8)	1.6	(3)
Sugar maple	3.8	(1)	2.1	(1)	7.1	(6)	4.9	(9)
Beech	4.4	(2)	7.1	(4)	6.0	(5)	2.9	(5)
Red maple	7.3	(3)	5.3	(3)	4.5	(4)	2.3	(4)
White ash	3.4	(1)	2.2	(1)	1.8	(1)	1.3	(2)
Pin cherry	23.7	(9)	21.8	(12)	23.5	(18)	11.4	(21)
Striped maple	.1	(—)	.9	(1)	2.2	(2)	1.6	(3)
Raspberry	61.2	(22)	46.6	(26)	40.8	(32)	15.6	(29)
Aspen	1.4	(1)	.6	(—)	1.0	(1)	.0	(—)
Other	5.2	(1)	10.9	(7)	13.2	(10)	9.6	(18)
Total	277.4	(100)	178.2	(100)	126.8	(100)	54.5	(100)
			COMPARTMENT 31					
Paper birch	56.8	(20)	24.7	(14)	5.9	(6)	.7	(3)
Yellow birch	88.3	(32)	23.8	(13)	4.0	(4)	.1	(1)
Sugar maple	11.1	(10)	23.0	(13)	35.9	(37)	6.7	(21)
Beech	11.1	(4)	8.9	(5)	13.0	(13)	6.4	(25)
Red maple	3.0	(1)	3.1	(2)	1.0	(2)	.9	(4)
White ash	5.1	(2)	5.4	(3)	1.9	(2)	—	(—)
Pin cherry	5.0	(2)	7.7	(4)	9.0	(9)	4.7	(18)
Striped maple	3.0	(1)	3.1	(2)	5.0	(5)	1.2	(5)
Raspberry	61.0	(22)	49.4	(28)	15.8	(16)	6.7	(21)
Aspen	1.7	(1)	.8	(—)	—	(—)	—	(—)
Others	15.5	(5)	28.2	(16)	5.9	(6)	.8	(2)
Total	278.8	(100)	178.1	(100)	98.1	(100)	25.3	(100)

dominant on only 8 to 22 percent of the 1/4-milacres (table 1). Undesirable stems such as pin cherry, striped maple, aspen, raspberry, maple sprouts, and beech root suckers were dominant on most of the area. The larger pin cherry, aspen, and striped maple had reached heights of 10 to 12 feet and base diameters of 1 inch or more, and in some places they grew so profusely as to exclude all other species.

Effects of Seedbed

Differences in birch stocking due to seedbed were highly significant. Skidroads contained several times as many birch seedlings as did the disturbed seedbeds, and these in turn contained several times as many as the undisturbed seedbeds (table 2). Birch seedlings were in a dominant position in significant numbers only on the skidroads (table 3). The distribution of birch seedlings was also much better on skidroads and disturbed seedbeds; nearly all plots of these seedbeds contained some birch, whereas more than half of the undisturbed (including slash) plots did not contain a single birch seedling (table 1). The concentration of birch seedlings in and around the skidroads was clearly evident upon casual observation.

Birch stocking in the skidroads averaged 3½ to 4 seedlings per square foot. Undisturbed surface, which occupied two-thirds to three-fourths of the patch areas, contained only 1 seedling in every 2 to 5 square feet. Obviously the scarification that occurred during logging greatly increased the stocking of birch. The effect of scarification would have been even more sharply revealed if the seed supply or weather conditions had been less favorable than they were during the year that the patches were cut.

The distribution of other species by seedbeds is shown in tables 2 and 3. Raspberry was the only species except the birches that showed significantly higher stocking on the skidroads and disturbed seedbeds. Differences among seedbeds for the other species were small and nonsignificant, except that there were fewer stems of all species in the slash piles than elsewhere.

Differences between Compartments

Compartment 45 had more paper birch and pin cherry, and less sugar maple, beech, and striped maple than compartment 31 (table 2). These differences were significant. The most noticeable differences were in the dominant stems (table 3). In compartment 45, pin cherry far outranked all other species: it occurred in such large numbers and grew so rapidly that it was dominant on nearly two-thirds of all plots. In compartment 31, pin cherry was a relatively minor component; instead, striped maple and beech root suckers were most often dominant.

Table 3.—Stocking in patch cuttings, by species and seedbed condition, in percent—dominant stems

Species	Skidroad	Disturbed	Undisturbed	Slashpile	All seedbeds
		COMPARTMENT 45			
Paper birch	8	1	2	4	4
Yellow birch	2	—	—	1	1
Sugar maple	—	—	2	9	2
Beech	2	6	8	4	6
Other merchantable species	—	—	2	8	2
Pin cherry	64	69	61	39	58
Striped maple	1	7	7	5	6
Raspberry	20	16	13	18	16
Other	3	1	5	12	5
Total	100	100	100	100	100
		COMPARTMENT 31			
Paper birch	13	5	1	3	5
Yellow birch	4	—	3	—	3
Sugar maple	3	7	17	13	12
Beech	16	23	28	27	24
Other merchantable species	3	2	4	—	3
Pin cherry	2	10	7	23	7
Striped maple	16	25	26	17	23
Raspberry	43	20	9	16	19
Other	—	8	5	1	4
Total	100	100	100	100	100

These differences between compartments 45 and 31 are typical of those observed between other second-growth and old-growth areas. Successful regeneration has frequently been reported after cuttings in old-growth timber *(1, 2)*. Seedlings of maple, birch, and other valuable species become established in large enough numbers to produce a satisfactory stand. Similar cuttings in second-growth are less satisfactory because pin cherry, red maple sprouts, and other undesirable stems dominate the new stand *(5)*. The present compartments conform to this general pattern.

An important point to note here is that the lack of dominant birch in the second-growth compartment 45 was not due to failure of birch seedlings to get established. There were many more birch seedlings in compartment 45 than in compartment 31. Yet twice as many plots were stocked with dominant birch and three times as many were stocked with dominant merchantable species of seedling origin in compartment 31 as in compartment 45. The aggressive competition from pin cherry and the lack of advance reproduction of sugar maple and beech appear to be responsible for the less favorable situation in compartment 45.

Origin

Origin of regeneration is important because it affects initial growth rate and ultimate quality of the tree. In general, sprouts and root suckers are undesirable. Most of the maple sprouts in these patches were eliminated 1 year after the cutting by basal spraying with herbicide. In spite of this treatment, sprouts and root suckers are an important component of the reproduction.

The proportions of all tallied stems of merchantable species that were of vegetative origin are shown in table 4. Note that proportionately more sprouts and root suckers were dominant than seedlings of the same species. For example, only 2 percent of the sugar maples in compartment 31 were sprouts; yet 26 percent of the sugar maples in a dominant position were sprouts. A similar situation prevailed in the other species.

Table 4.—Origin of stocking in patch cuttings: percentage of tallest stems that were of vegetative origin

Species	Compartment 45		Compartment 31	
	All stems	Dominant stems	All stems	Dominant stems
Paper birch	1	12	—	—
Yellow birch	—	—	1	15
Sugar maple	1	6	2	26
Beech	50	88	50	84
Other merchantable	2	33	3	33
All merchantable species	5	41	7	53

Table 5.—Proportions of paper birch and yellow birch in three categories of stems, in percent

Category	Compartment 45		Compartment 31	
	Paper birch	Yellow birch	Paper birch	Yellow birch
All birch stems	68	32	43	57
Tallest birches—all ¼-milacres	76	24	59	41
Tallest birches—birch-dominated ¼-milacres	86	14	62	38

Experience has shown that elimination of maple sprouts (particularly red maple) is desirable; otherwise these unwanted stems will outgrow and eventually suppress all other trees within a sizeable area. Beech root suckers, which are more difficult to treat with basal sprays, also may be troublesome when they are as numerous as they were in compartment 31.

Data on origin of weed species are not shown in table 4. It was originally assumed that all of these species originated from seed, and this certainly was true of the pin cherry and raspberry. However, only a few of the aspen started from seed. This species appeared in quantity only in patches where it had been present before the cutting, and here all the larger aspen stems examined were found to be root suckers.

Striped maple was in certain respects the most surprising of the four weed species. Although of seed origin, most stems were at least 10 years old. They apparently had become established before the cutting and had managed to survive in the dense shade without making much growth. Once provided with full sunlight, however, they began growing at the rate of 2 or 3 feet a year. Examination of adjacent uncut areas confirmed the presence of many suppressed striped maple seedlings.

Paper Birch versus Yellow Birch

There were more paper birch than yellow birch in compartment 45, but the reverse was true in compartment 31. This almost certainly was due to differences in the seed sources. However, paper birch does appear to be better able to compete than yellow birch. Even in compartment 31, where yellow birch was more prevalent, paper birch was more often dominant (table 5).

HEIGHT GROWTH

The birches were generally among the shortest stems, averaging less than 3 feet tall. Raspberry averaged about 3 feet, and beech and sugar maple ranged between 3 and 4 feet. Pin cherry and striped maple were the tallest species, averaging about 6 feet.

Seedbed-Growth Relationships

The tallest seedlings were found in the undisturbed areas, and the smallest ones in the skidroads and slash piles (table 6). These differences were statistically significant. In an earlier study *(3),*

Table 6.—Mean heights in feet, by species and seedbed condition, based on dominant stems by ¼-milacre sub-plots

Species	Skidroad	Disturbed	Undisturbed	Slash	$\bar{x}$
		COMPARTMENT 45			
Paper birch	2.3	2.4	4.1	2.8	3.0
Yellow birch	2.6	—	1.0	1.1	1.8
Sugar maple	3.2	3.9	3.8	3.2	3.3
Beech	3.2	3.9	3.8	3.2	3.7
Other merchantable	—	5.0	2.6	3.0	3.1
Pin cherry	5.5	5.9	6.2	4.9	5.9
Striped maple	3.3	3.8	4.1	4.2	4.0
Raspberry	3.1	2.9	3.1	2.5	2.9
Other	1.9	5.0	6.9	2.4	2.4
$\bar{x}$	4.5	5.1	5.3	3.7	
		COMPARTMENT 31			
Paper birch	2.0	1.6	2.0	0.4	1.9
Yellow birch	1.8	—	3.6	—	2.9
Sugar maple	2.7	4.6	3.9	4.3	3.8
Beech	2.3	2.6	3.2	2.5	3.0
Other merchantable	2.7	1.8	3.4	—	3.2
Pin cherry	3.0	2.2	2.3	2.9	2.3
Striped maple	4.4	6.3	6.4	6.3	6.0
Raspberry	3.1	3.2	2.8	2.9	3.0
Other	—	4.0	2.8	—	3.0
$\bar{x}$	3.0	3.8	4.0	3.5	

growth on mineral soil seedbeds was found to be less than on organic seedbeds, apparently due to higher nutrient levels in the organic matter. Lower nutrients may be one reason for the poorer growth in the skidroads. Other possible reasons are the greater number of stems on the skidroads, which may depress the growth rate, or heavier deer browsing.

Poor growth in the slash piles may be a result of slower restocking (younger seedlings) in these areas. Although it has sometimes been suggested that slash minimizes deer browsing, this seems relatively unimportant in these cuttings, particularly in reference to the birches, because so few birch seedlings became established in the slash.

Growth in compartment 45 was significantly better than in compartment 31, average heights being 1 to 1½ feet greater. The reasons for this difference are uncertain; site, elevation, and size of cut patches are factors that may have had some differential effects on growth.

Would Weeding Help?

There is much controversy over the effects of weed tree competition. Some foresters feel that this competition does little or no harm. Some even feel that it is beneficial by reducing deer damage and encouraging rapid natural pruning. Others feel that pin cherry in particular may limit birch regeneration where the cherry occurs in large numbers.

By the end of the first growing season it was apparent that pin cherry and raspberry competition would be severe in compartment 45. To get some evidence on the effects of this competition, an exploratory weeding was done in two of the patches during June

Table 7.—Quarter-milacres containing free-to-grow birch, compartment 45, in percent

Condition	Not weeded	Weeded
Skidroad	9	41
Disturbed	3	50
Undisturbed	2	9
Slash	4	—

of the second year. All pin cherry and raspberry seedlings were removed (pulled out by the roots) in half of each of the two patches. The areas thus weeded were tallied and summarized separately.

Some of the results of the weeding are shown in table 7. Removal of pin cherry in particular left many more birch seedlings in a free-to-grow position. Whether or not this treatment will affect the ultimate growth or survival of the released seedlings cannot be determined yet. But if the competition is as severe as it appears, weeding would help.

Summary

Patch cuttings of 1/10 to 2/3 acre were made in both second-growth and old-growth northern hardwood stands and were examined 3 years later for the amount and kind of reproduction that was developing. The data demonstrated that such small clearcuttings can be used successfully to regenerate the highly desirable paper and yellow birches. Seedlings of both species became established in large numbers in all patches.

Seedbed condition was the most important factor affecting early birch establishment. Seedlings were much more numerous where mineral soil had been exposed in skidroads and other disturbed areas than in areas that had not been disturbed by logging. However, seedling growth was best in the undisturbed areas, presumably because of the greater supply of nutrients in the organic soil layers.

Competition from weed species and from sprouts and root suckers of commercial species was important in limiting the number of birch seedlings able to attain a free-to-grow position. Such competition was particularly severe in the second-growth stand. In general, birch seedlings on disturbed seedbeds were in a better competitive position than those on undisturbed seedbeds.

A small experimental weeding in two patches showed the possibilities of such treatment for releasing overtopped birch seedlings, at least temporarily, from suppression by faster growing competitors.

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Deer Browsing of Hardwoods in the Northeast

by Elwood L. Shafer, Jr.

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

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Deer Browsing of Hardwoods in the Northeast

A REVIEW AND ANALYSIS OF THE SITUATION AND THE RESEARCH NEEDED

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Introduction

THE white-tailed deer *(Odocoilens virginianus)* is by far the most important big-game animal in the Northeast, both in hunter interest and in its damaging effects to field and forest. In the absence of predators, deer have the potential to increase rapidly to greater numbers than the natural food supply will support. If hunting regulations are unduly restrictive, excessive populations build up. The animals decline in size and vigor, and both farm crops and forest reproduction suffer. Winter browse is the crucial item in the year-round food supply; when it fails during a severe winter, mass starvation may occur.

The most obvious and direct answer to this problem is to reduce the deer populations by more liberal hunting regulations. A second measure, which ideally should be coordinated with population control, is to manage non-agricultural land for greater browse production. However, the latter measure is easier said than done; it requires much technical knowledge, which forest and wildlife technicians are just in the process of acquiring. Such knowledge is particularly essential where management for browse is to be integrated into multiple-use systems of land management.

Deer research in the past has been concentrated on herd control, and information on this aspect of deer management is now nearly adequate although not yet applied in many places because of the public's overly protective attitude. Once deer are in balance with their natural food supply, the primary multiple-use objective on many areas will be to maintain a healthy herd at a population level that the range can continuously support without the tree reproduction that is essential for sustained timber production being destroyed.

To provide guides for accomplishing this, extensive research is needed in the timber-wildlife phase of multiple-use land management to determine, for specific timber types and regions, what constitutes a proper balance between timber and deer. Certain relationships between deer and forest management practices that apply to, or are adaptable to, sections of the Northeast have already been summarized in several studies (Little *et al.* 1958, Gill 1957c, Banasiak 1961, Jenkins and Bartlett 1959, Latham 1950).

This report deals with the production, utilization, and measurement of hardwood deer browse in the forests of the Northeast. It is basically a review of pertinent literature. To the extent that the cited literature has been selected and interpreted, that conclusions have been drawn, and that recommendations have been made, this report is also an analysis of the problems and research needs in managing forest land for deer. The purpose is to provide a reference tool for both administrators and researchers involved in the technical problems of timber-deer management in this region.

As indicated above this report is concerned primarily with hardwood browse — the twigs, buds, and leaves of woody plants of the hardwood category (as opposed to softwoods or conifers). However, information on other forms of vegetation or on non-indigenous species has been included when it seemed relevant to the discussion.

References are made in this report to certain concepts that lend themselves to precise definition only in the context of specified conditions and management objectives in particular situations. Among these concepts are "carrying capacity," "in balance with the food supply," and "multiple use."

The concept of carrying capacity has been discussed by Edwards and Fowle (1955), who state that "carrying capacity is determined by the whole environment, and with some reservations, the number of animals upon a unit of range is in itself a measure of the carrying capacity of that area." However, they say that the factors in the environment should be considered separately when determining carrying capacity. These factors usually follow Liebig's "Law of the Minimum," with the most critical factor having a major influence.

"Multiple use" is both a concept and a management system. In the context of this review, it involves planned maximum use of a given area for deer habitat and timber production; it means that the intensity and pattern of timber cutting should be guided, insofar as is feasible, by multiple-use rather than single-use criteria in order to meet the increasing demand for both timber and deer. And, although not further discussed here, it should be understood that habitat for other wildlife, and management for other purposes—such as watershed protection, recreation, and scenic values—may also be involved. Multiple use explicitly requires management for various renewable resources "over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions."[1]

The Browse Situation

The present condition of browse in the Northeast is the result of past land-use (Leopold 1950, Bennett 1957, and Latham 1959). In the late 1800s much of the timber throughout the Northeast was cut heavily. As a result, vast areas of young sprout-growth in the early 1900s provided abundant deer food; and deer populations increased rapidly. When the sprout growth developed into even-aged sapling and pole stands (fig. 1), such as those that now occupy more than 52 percent of the commercial forest land in the Northeast (U. S. Forest Service 1958), the much reduced understory vegetation could not support the large deer herds and the following results, as listed by Latham (1950), occurred: (1) reduction of total carrying capacity; (2) reduced populations of certain small game; (3) decreased or complete loss of forest reproduction; (4) crop damage; (5) abnormalities of deer themselves caused by malnutrition; (6) reduced antler size; (7) reproductive abnormalities; (8) winter mortality; and (9) disease.

However, heavy browsing is not always detrimental. In deeryards in northern Michigan, which contained many of the same tree species found in the Northeast, Davenport *et al.* (1953) observed that deterioration occurred almost as rapidly in areas that were not used by deer as in areas that were used. The deterioration comes about through self-pruning of the trees and suppression of the undergrowth by shading, and from damage to the undergrowth by snowshoe hares. The authors concluded that "Good management, therefore, should strive to prevent underutilization as well as overutilization of those yards having high browse production."

Webb (1957), in discussing overbrowsing in Northeastern forests, commented that, at some stages of a forest rotation,

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[1] Multiple use as it relates to management for timber and deer is defined in the Multiple Use and Sustained Yield Act of June 12, 1960, passed by the 86th Congress (Public Law 86-517) as a directive for the administration of the National Forests.

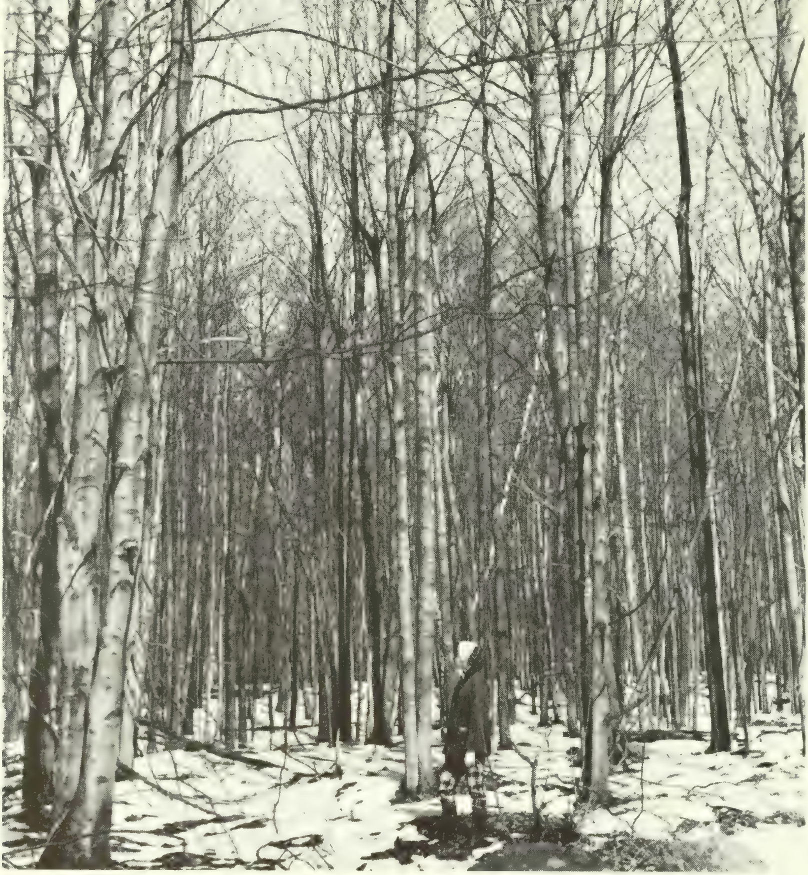

Figure 1.—A typical even-aged (45 years) sprout-origin stand of northern hardwoods with practically no reproduction or browse in the understory.

". . . heavy browsing is allowable and perhaps even desirable . . . but . . . at other times in the rotation even light browsing may be detrimental to the forest . . ." In another study, Webb *et al.* (1956) stated that deer were not a significant factor in controlling the vegetation of a mature hardwood forest in the Adirondack Mountains of New York State. However, one of the most important facts brought out by these and other studies is that sustained-yield forestry and production of the maximum number of deer are incompatible (Little *et al.* 1958).

Thus a major problem of the multiple-use land manager in the Northeast has become: For a given area of forest land, to determine the best way to integrate sustained timber and deer-browse production so that management of one as a key value will complement the other to the highest possible degree. The problem becomes even more complex when the manager must consider other products of the land such as water and other wildlife besides deer.

Several authors have stated or implied that deer herds should be reduced and held at or below the existing carrying capacity of the range for 3 to 6 years before attempting a management program for sustained integrated production of timber and deer (Wingard 1959, Dahlberg and Guettinger 1956, Robertson and Wingard 1959, and Stoeckeler *et al.* 1957).

Single-Use Management

Deer-browse management practices in the past have been concentrated largely on noncommercial browse production rather than on integrated timber and browse production. The primary, and sometimes only, objective of most methods has been to lower a maximum amount of what Webb *et al.* (1956) referred to as the "photosynthetic zone," so that energy stored by plants is within reach of the deer. Fortunately, single-use management for browse is gradually being replaced by multiple-use land management practices.

It has been suggested that land devoted to single-use management for deer-browse be low-quality sites incapable of pulpwood or timber production (Grange 1949). However, this practice seldom can be followed in the Northeast because most low-quality sites either cannot produce much browse, or the browse that is produced on them is unpalatable or unnutritious, and hence is not utilized. The scrub oak *(Quercus ilicifolia)* barrens in parts of eastern and central Pennsylvania are a case in point. Therefore, if deer-browse management were relegated to only the poor sites, only poor deer or few deer might logically be expected. That poor sites result in poor deer has not actually been demonstrated; and in view of deer mobility and our limited knowledge of deer nutrition, perhaps few deer is the more reasonable assumption.[2] The integration of deer and timber management on the better forest sites will be discussed in a later section.

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[2] Personal correspondence with Dr. James Jordan, project leader, Forest Recreation and Wildlife Laboratory, U. S. Forest Service, Warren, Pa.

Noncommercial browse-production methods have included the cut-and-bend method (fig. 2), complete severance of trees, bulldozing, fire, and ground and aerial application of herbicides. These methods may be useful (1) to temporarily relieve deer pressure in areas of excessive damage to tree reproduction, and (2) to provide food for concentrated deer herds on winter range. Several of these methods also seem adaptable to multiple-use land management.

Cutting

The cut-and-bend method, as described by DeBoer (1952), Gill (1957c), Swift (1953), and Chase and Severinghaus (1949), and complete severance of stems, as noted by Krefting (1941) and Morriss (1954), are the two principal methods used in noncommercial browse cutting. The sprout growth of many hardwood species that results from these methods usually is available to deer for about 10 years (DeBoer 1952). However, as number of twigs per sprout clump increases with age, the twigs available to deer decrease in size (Krefting 1941).

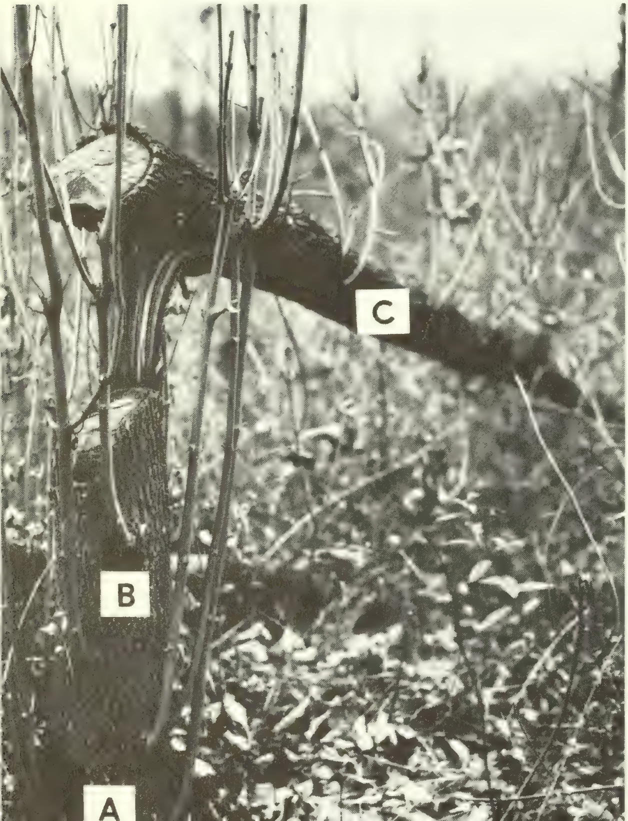

Figure 2. — The cut-and-bend method, showing the typical sprouting habit of many hardwood species: *A*, from the root collar; *B*, from the stump above the root collar; *C*, from the felled stem.

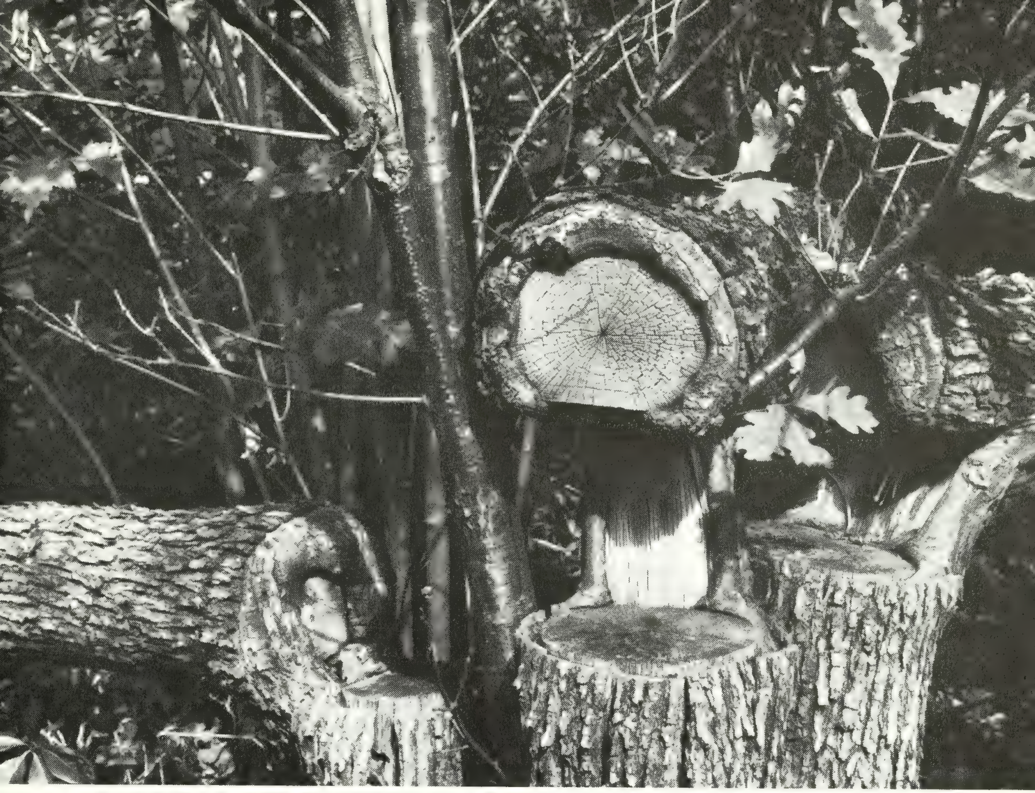

Figure 3.—With the cut-and-bend method, callus tissue often forms at the bend. This keeps the felled crown alive for a longer period of time.

In the cut-and-bend method, trees are felled by cutting the main stem about three quarters through, thus leaving the top connected to the root system. This keeps part of the crown alive for several years, and also stimulates sprouting from the stump. If callus tissue forms at the bend (fig. 3), the felled crown remains alive for a longer period. In pole and sawlog-size stands of the northern hardwood-hemlock type in northeastern Wisconsin, Stoeckeler *et al.* (1958) found that crowns of felled hardwood trees contained an average of 13 pounds of browse for each square foot of basal area.

The most vigorous sprout growth of many hardwood species is obtained when stems are cut to 12-inch or lower stumps (Krefting 1941, and Morton and Sedam 1938). Unlike most species, beech *(Fagus grandifolia)* when cut sprouts mostly from the tops of the stumps (fig. 4).

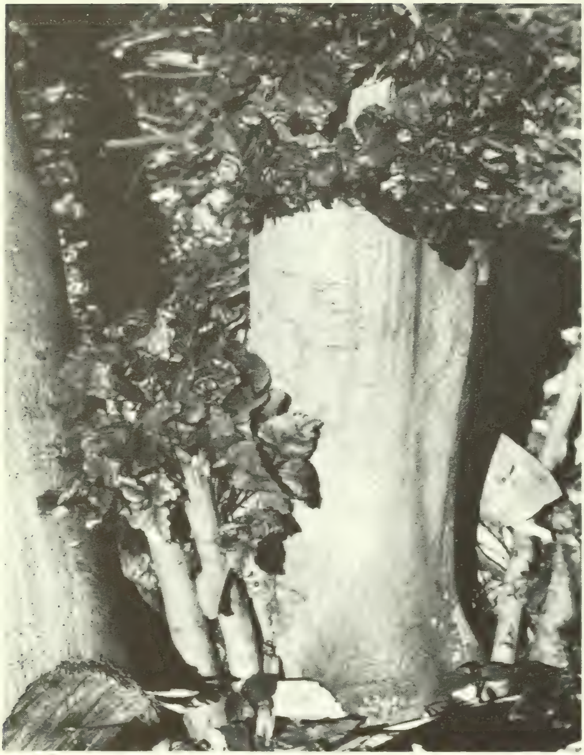

Figure 4.—Typical sprouting habit of beech.

The size and age of a tree affect its browse-production potential. In hardwoods, sprouting ability (and thus browse production) of stumps declines sharply with age (Hawley and Smith 1954) and with diameter increase (fig. 5) above 8-10 inches (MacKinney and Korstian 1932). Hawley and Smith (1954) have explained that, as bark thickness increases with age of a tree, the possibility decreases for dormant buds to break through and grow. Moreover, dormant buds will not sprout if, during growth, the connection is broken between the pith of the bud and the pith of the original stem.

Gill (1957a) recommended November through March as the best time to cut for hardwood browse in Maine: "This makes tops available when needed most and also produces as much stump growth as cutting at any other time."

Morriss (1954) proposed that, in commercial hardwood logging operations in North Carolina, the openings be shaped to

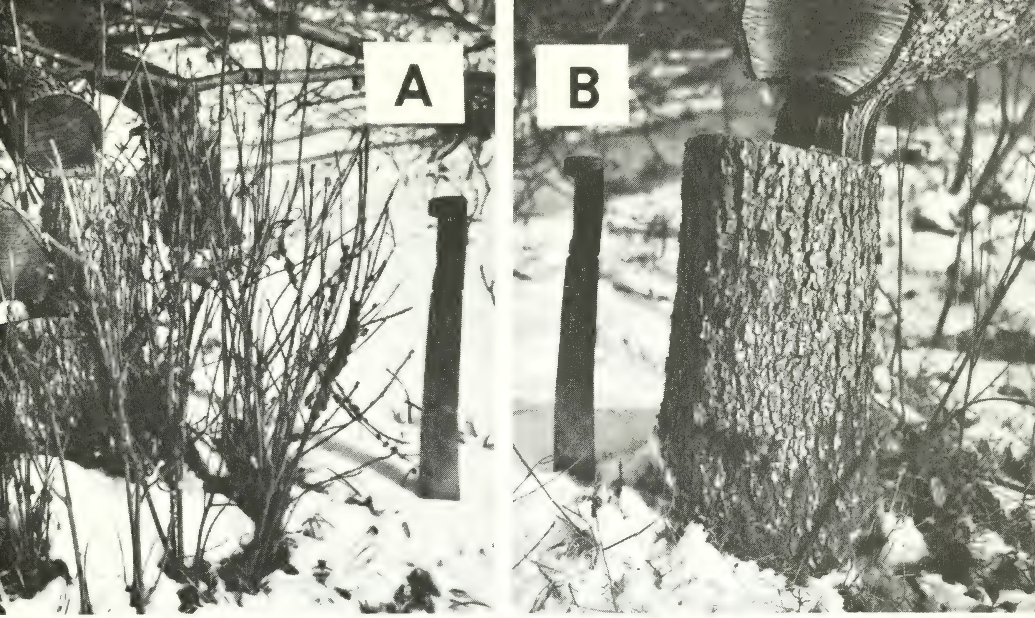

Figure 5.—Sprouting ability of stumps declines sharply with diameter increase. Here several white oaks *(Quercus alba)* of approximately the same age (34-38 years) were cut for browse production: *A*, sprouts from stumps of 2- to 3-inch d.b.h. trees produced abundant browse. *B*, sprout growth was insignificant from the stump of a typical 8-inch d.b.h. tree.

maximize the amount of border or edge so as to increase browse production and utilization. For young hardwood stands in Pennsylvania, Morton and Sedam (1938) suggested ". . . clearcutting in zigzag strips 50 to 90 feet wide . . . The length of slashing can be anywhere from 300 to 600 feet, depending upon local conditions . . . The trees should be felled back into adjoining timber to provide more cover and additional sunlight for shrub production at the edges of the cut strip."

Morton and Sedam (1938) also recommended repeating cuttings at intervals of a few years on the same areas. However, Hawley and Smith (1954) stated that a progressive decline in vigor occurs in most tree species when repeated cuttings are made on the same root stocks at relatively short intervals of time; and further, that frequent clearcuttings result in a relatively thin canopy and exposure of the forest floor to erosion and desiccation.

In discussing several methods of regulating chamise brushlands in California, Biswell (1961) stated that deer like to feed in areas that are partially open, and will spend more time feeding where shrubs are separate or at the edge of a patch than where the plants are growing densely. This principle also seems pertinent in the Northeast: browse within the dense thickets that often develop after clearcutting tends to be inaccessible and therefore of little benefit to deer, no matter how abundant or palatable it may be. Another disadvantage of clearcutting, explained by Gill (1957a), is that browse grows out of reach of deer more quickly than in other types of cutting (fig. 6).

Cuttings of mast-producing species such as oak and beech have been made specifically for browse in young stands in Pennsylvania. Where 50 to 75 percent of the overstory was removed, residual trees developed a more open crown with increased capacity to produce mast (Morton and Sedam 1938). Suggestions for this type of management also have been made by Reid and Goodrum (1957) for the longleaf pine type. Their recommendations, although pertaining to a different region, would seem to be generally applicable to the Northeast.

Herbicides

In addition to cutting, herbicides such as 2,4-D and 2,4,5-T have been used effectively for producing browse (Van Etten and Thomson 1959, Ruch 1957, Coulter 1958, and Jenkins and Bartlett 1959); and such browse is readily eaten by deer (Krefting *et al.* 1956, and Gysel 1957). Neither of these hormone-type herbicides nor ammate are toxic to wildlife. Haugen (1951) reported that, when experimental deer were fed ammate and ammate-treated foliage, the only effect it seemed to have was "to help them (the deer) gain weight."

With aerial application of herbicides, there are problems of drift, interception of spray by the overstory, lack of the desired selectivity, and the requirement that areas for treatment be fairly large. Some of these problems can be avoided by using mistblowers (MacConnell and Bond 1961).

Herbicides have been aerially sprayed in strips on large wildfire burns in California to retard development and maintain the brush cover in varying stages, but Biswell (1961) cautioned that this practice may also kill certain shrubs that are preferred by deer.

For hardwood areas in northern Michigan, Ruch (1957) recommended creating openings by aerial spraying of strips 30 to 50 feet wide and ¼ to ½ mile long. Preliminary data gathered

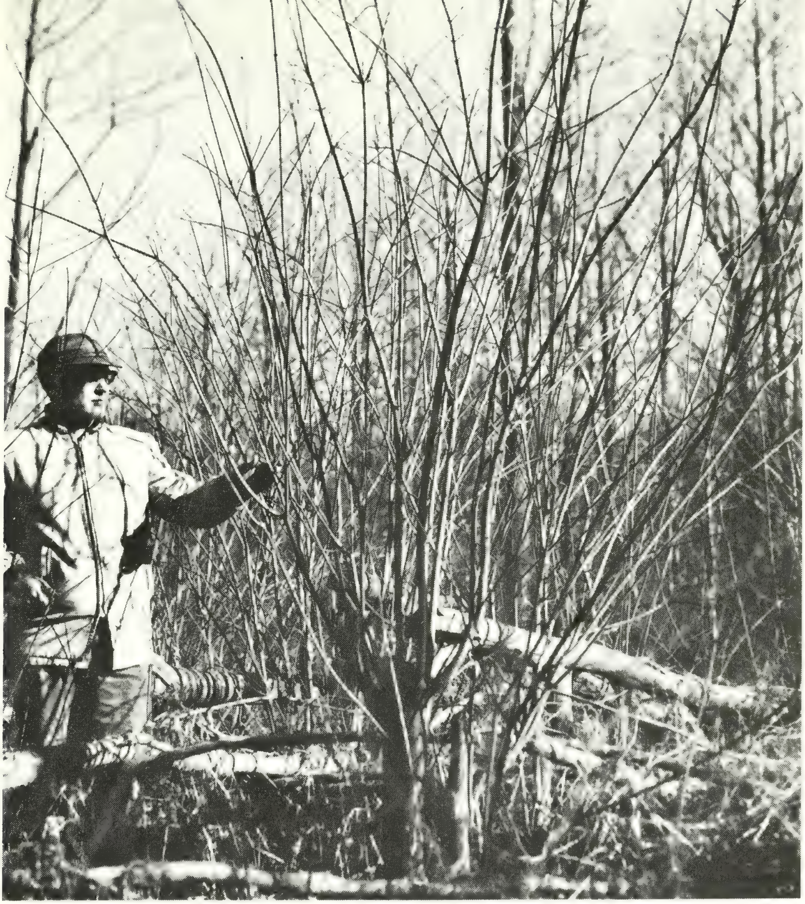

Figure 6.—Three-year-old sprout growth of a red maple stump in a clearcut area. Note how much of the browse has grown up out of the reach of deer.

by Krefting *et al.* (1960), for upland forest types in Minnesota, indicated that areas of 100 acres or less may be sprayed from the air for less than $4 per acre.

Krefting *et al.* (1956) reported that in spray treatments of mountain maple *(Acer spicatum)* with ground equipment at early bud-burst time, 2,4,-D at concentrations of 4,8, and 12 pounds ahg. was generally more effective than 2,4,5-T in inducing regrowth. As concentrations were increased, the number of stems and lineal feet of regrowth also increased. Breast-height applications generally resulted in greater stimulation of regrowth than basal treatments. Herbicide treatments were found to be significantly superior to fire for stimulating sprout growth, and stands could be treated with herbicides in winter much faster than they could be cut with axes. However, the cost of the herbicide offset the saving in labor time. Cost by either method was about $5 per acre. Ax cutting resulted in the most regrowth.

Gysel (1957) recommended girdling, rather than frill treatment with herbicide, for maximum sprouting and browse production. He also suggested that some trees be left untreated to create diversity of food and cover.

Not only browse, but herbage also, has been successfully increased for deer by the use of herbicides (Ehrenreich 1959, and Bramble *et al.* 1956).

Fire

Fire is probably the least desirable method for producing browse (Latham 1950, and Pond and Cable 1960); but, if properly controlled and limited to forest growth of little commercial value, fire may be a useful tool. In Wisconsin, fire eliminated a stand of practically worthless aspen, prepared a good seedbed, and permitted 20,000 to 30,000 stems of aspen per acre to emerge for deer browse (DeBoer 1952). Prescribed burning for forest-management purposes in the Pine Region of southern New Jersey has been useful in increasing browse production (Little *et al.* 1958). However, successful control burns for browse are limited by available men and equipment and by the few days when weather conditions are suitable (Jenkins and Bartlett 1959).

Fire for creating browse has probably been used most successfully in the chaparral area of California—often in combination with bulldozing, disking, and herbicide treatments (Biswell 1961). In California, the protein content of browse was found to be higher in burned areas than in unburned areas (Shantz 1947, and Taber and Dasmann 1958). In Maryland, DeWitt and Derby (1955) found that a high-intensity fire produced significant increases in the protein content of red maple *(Acer rubrum)*, white oak *(Quercus alba)*, flowering dogwood *(Cornus florida)*, and roundleaf greenbrier *(Smilax rotundifolia)* browse; but the results suggested that repeated high-intensity fires are necessary to maintain this high-protein condition. The adverse effects of burning are that it may lower the fertility and productivity of the soil (Latham 1950), and it reduces or eliminates many browse species preferred by deer (Pond and Cable 1960).

Bulldozing

Bulldozers have been used to push down trees so the crowns are available to deer (DeBoer 1953). Part of the root system is left in place to keep the crown alive for several years. To lessen the damage to root systems, Forbes and Harney (1952) suggested that bulldozing be done in the spring when the ground is moist and soft. In pole-stage beech-birch-maple stands of Pennsylvania, large bulldozers (D-7s) "experienced little difficulty in pushing over trees" and then "moving ahead, always overrunning the trees"; smaller bulldozers (D-4s) "could not negotiate through many of larger tangles" and had to move around the bulkier down trees rather than over them (Forbes and Harney 1952). Tractors equipped with tree-cutter blades also have been used to increase available browse (Beale 1960).

In pole-size hardwoods of central Pennsylvania, Sharpe (1957) reported that browse utilization on bulldozed 5-acre openings was relatively small as compared to that on 1-acre openings.

Although a bulldozer can push down hundreds of pounds of browse a day, as noted by DeBoer (1952), bulldozing obviously entails many of the same disadvantages for browse utilization as clearcutting.

Multiple-Use Management

Very little research has been done on multiple-use management methods for integrated timber and browse production. Various procedures have been proposed, but few experiments have been made in the Northeast to test them. The following recommendations and observations seem relevant to multiple-use management under Northeastern conditions:

1. Lauckhart (1955), in reference to the West, pointed out that browse conditions in any large area will vary considerably—some localized parts of it may be overstocked and other parts may be understocked. He recommended, therefore, that the management of a large area be based on the average rather than the extreme conditions.

2. Dahlberg and Guettinger (1956) suggested that management in Wisconsin be directed mainly toward second- and third-choice browse species, rather than toward re-establishment of

first-choice species that have disappeared because of heavy deer pressure.

3. Graham (1954) emphasized that mixtures of softwoods with hardwoods are essential for good browse utilization in Michigan. He noted that, without hemlock in mixture, deciduous hardwood stands are open to winter winds and therefore become uninhabitable for deer during severe weather. This suggested that winter deer range perhaps could be expanded by underplanting browse-resistant conifers, such as white spruce *(Picea glauca)*, in areas where browse cuttings have been made.

4. In Adirondack forest types, Barick (1945) reported that transition zones between different types have the greatest potential for browse-habitat improvement because of the variety of cover that can be created.

5. Morriss (1954) has shown for hardwood types in North Carolina that improvement cuttings provided approximately the same amount of usable browse as clearcuttings or modified clearcuttings.

6. Grisez (1960) noted that, where deer are abundant in Northeastern Pennsylvania, slash from commercial hardwood cuttings should not be reduced because it provides some protection to desired tree seedlings. The planned placement and preservation of slash would seem to be especially worthwhile for reproduction and harvest cuts. However, slash less than 2 feet high seldom affects browse utilization (Gill 1957b).

In northern Michigan, the most practical method for producing browse has been "a continuous commercial timber cutting program covering the largest total area that the market will permit, well distributed in small blocks, and with the shortest possible period between cuts" (Jenkins and Bartlett 1959). This method seems especially appropriate to group selection and shelterwood cutting—silvicultural systems that often are recommended for northeastern hardwood forest management. Small forest openings created by this type of cutting may also increase groundwater supply, as suggested by Sharp (1957), and thus qualify as a good watershed-management practice. Cutting cycles would have to be short—probably every 10-15 years—to maintain desirable amounts of browse. Over an entire rotation, management of this kind should result in a wide variety of age classes, densities, and stand compositions. Such a variety of conditions is recommended as good deer habitat by Dahlberg and Guettinger (1956).

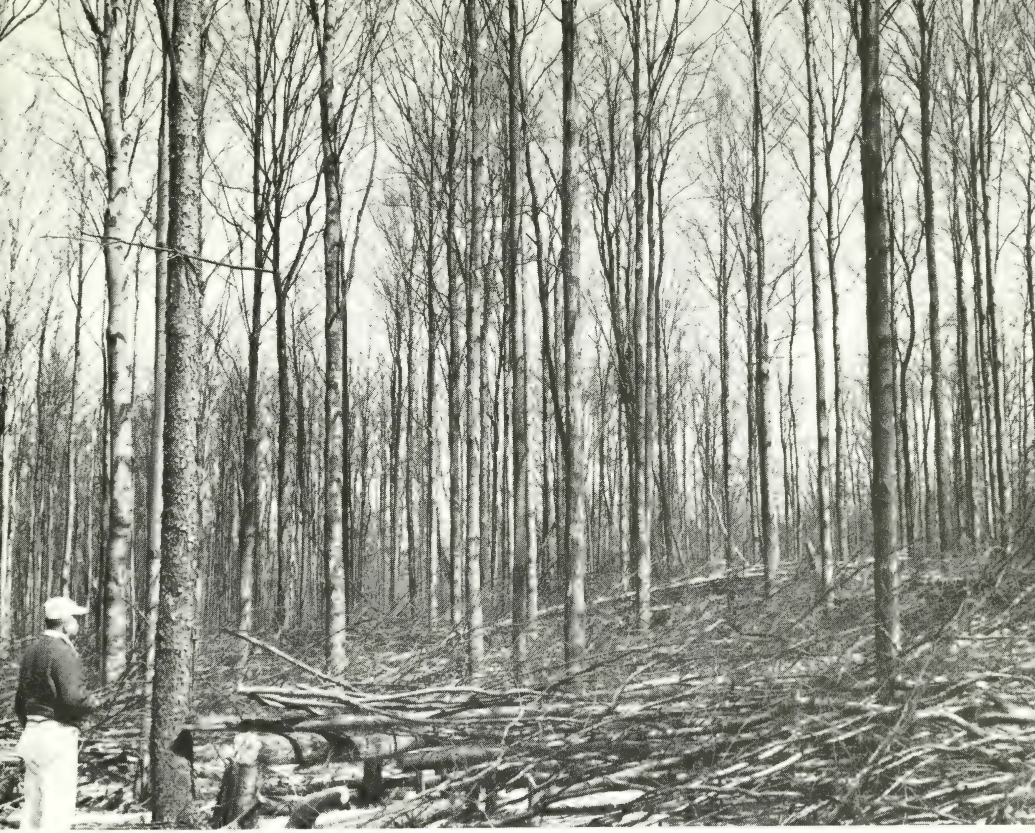

Figure 7.—Results immediately after thinning the same stand shown in figure 1. The multiple-use objective was to produce accessible browse for deer and to increase the timber quality and growth of the residual stand.

Intermediate silvicultural cuttings (Hawley and Smith 1954), in which suppressed or poor-quality trees in 40- to 50-year-old even-aged hardwood stands (fig. 7) are removed, seem especially appropriate for integrated timber-browse management for two reasons: (1) trees in these stands sprout more profusely than older trees and thus produce more browse; and (2) thinning in pole-size stands generally yields more return on the investment than other cultural operations (Webster 1960). Another probable advantage of intermediate cuttings would be that the residual overstory would reduce the rate of understory height growth; hence browse would remain accessible to deer for a longer period of time. Either cut-and-bend or complete severance of stems could be used to fell trees in this type of cutting; if maximum browse production were the objective, the cut-and-bend method would seem to be indicated. Intensity and distribution of such multiple-use cutting would depend on overall management objectives.

In older stands, it may be necessary to restrict browse-production operations to cuttings that improve stand composition and quality; that is, to remove only trees of undesirable species, form, or condition. Primarily, these would be salvage or sanitation cuttings (Hawley and Smith 1954); and they would produce less browse, which would be more sensitive to browsing pressure, than earlier intermediate cuts. For example, Halls and Crawford (1960) found, for upland hardwood forests in Arkansas, that as stand size and density increased, browse was reduced considerably even when subjected to only light browsing.

In North Carolina, post-sale cultural work has been intensified so that areas treated for browse production are dispersed within the commercial sale area (Morriss 1954). Commercial thinning of ponderosa pine *(Pinus ponderosa)* stands in the Black Hills of South Dakota (Pase and Hurd 1957) and of loblolly pine *(Pinus taeda)* plantations in Louisiana (Blair 1960) have also resulted in increased production of hardwood browse.

Grange (1949) emphasized the point that, regardless of the objectives in any timber-browse management program, no high-quality timber tree should be felled for browse unless it is to be utilized for wood products. Presumably, the browse created by felling a high-quality tree is not sufficient to offset its timber value. However, comparisons of values between the timber in a tree and the browse it is capable of producing are extremely difficult to make because of the intangible values associated with the recreational aspects of a healthy deer population.

Browse Nutrition and Palatability, and Deer Preferences

The nutrition and palatability of browse, and the preferences of deer, are complex and important biological factors that must be given careful consideration in wildland management procedures. The following discussion involves only a few of the more important items in this phase of timber-deer management and research.

French and McEwen (1955) reported that "Experimental feeding studies with deer have been rather few in number because of the great difficulty and expense as well as the long period of time required in conducting them." Magruder *et al.* (1957) referred to "a complete review of literature on deer nutrition" by French *et al.* (1956), which included only 11 references. French's list indicated the limited amount of nutrition research that had been done at that time. And not much has been done since.

An average daily nutritional requirement for deer is difficult to determine because deer exhibit "extreme seasonal changes in body weight and feed consumption" (Magruder *et al.* 1957). French and McEwen (1955) found, in a study of measured nutritive requirements of 22 penned white-tailed deer in Pennsylvania, that the daily food requirement of a 150-pound deer was "at least 10 to 12 pounds of good deer browse, of usual moisture content," and that the protein content of this browse should be 13 to 16 percent for optimal growth and antler development. In a continuation of the same experiment, Magruder *et al.* (1957) reported that: "Calcium and phosphorus requirements were closely interrelated. A deficiency of one was better tolerated if the other was present in adequate amounts . . . Best antler growth was obtained when deer were fed a high dietary level of 0.64 percent calcium and 0.56 percent phosphorus."

Protein content of browse is a critical factor in deer nutrition; Einarsen (1946) noted that black-tailed deer *(Odocoileus hemionus columbianus)* in Oregon could not survive long on a ration containing less than 5 percent protein. In discussing nutrient requirements of deer in California, Leopold *et al.* (1951) observed that the available twigs of choice, high-protein browse are nipped first; the deer are forced to eat species containing less protein as winter progresses and the supply of preferred browse decreases. They state further that "The mechanism by which a deer recognizes superior forage is unknown."

Protein content of various species of deciduous browse is greatest during the growing season and declines gradually to a low in winter (Dietz *et al.* 1958, Smith *et al.* 1956, and Hellmers 1941). C. M. Aldous (1945) found that protein was concentrated in the terminal buds of bitterbrush *(Purshia tridentata)*, with decreasing amounts in the lower portions of the twigs. The same may be true of hardwood species in general. Several researchers (Cook and Harris 1950, Einarsen 1946, Gordon and Sampson 1939, and Swank 1956a) have reported that the protein content of twigs decreases as a plant matures; and Taber and Dasmann (1958) found that regrowth of moderately browsed sprouts in California was higher in protein content than the original browsed portion.

Dahlberg and Guettinger (1956) and Trippensee (1948) concluded that browse plants of high palatability do not necessarily have high nutritional value. On the other hand, Leopold *et al.* (1951) found that the crude protein content of browse approximately followed the "gradient of palatability" among six shrubs on winter range in California. Obviously the interrelationship between nutritional quality and palatability of browse does not lend itself to simple generalization.

Deer in southwest Colorado were observed to choose browse containing the highest nutrients during each season, and this led Dietz *et al.* (1958) to conclude that two or three browse species cannot supply deer with an adequate diet. This suggests that browse-management practices should be designed to favor a number of species rather than just one or two.

Seasonal fluctuations in rainfall may influence a plant's nutrient content and its tolerance to browsing (Sharp 1958); plants can withstand heavier browsing during a wet summer than during a dry one.

Variations in nutrient content and species preference may often be related to soil types and site conditions (Gaines *et al.* 1954, Denny 1944, Cronemiller 1955, Hundley 1959, and Swank 1956b). Forbes (1959) observed that deer overbrowsed the understory of the beech-birch-maple type in south central Pennsylvania, but available browse in a surrounding oak-hickory type was only lightly utilized. Tarr (1953) found that deer in central Pennsylvania browsed more selectively on north slopes than on south slopes; however, the animals spent more time on the south slopes even though more browse was available on the north slopes.

Sharp (1958) stated that deer are very adaptable and can alter their food preferences to coincide with differences in habitat. Aldous (1938) reported that trembling aspen *(Populus tremuloides)* was not eaten extensively by deer in Minnesota, but Julander (1937) considered aspen a key species on the summer range in the Southwest. This comparison involves two different species of deer; but local deer stocks also may have different preferences (Leopold *et al.* 1951), and even individual deer in the same locality appear to vary in this respect (Deen 1938).

There have been many studies in which browse species were listed by degrees of deer preference (Bramble and Goddard 1953, Dahlberg and Guettinger 1956, Dalke 1941, Deen 1938, Gill 1957c, Little *et al.* 1958, and Stegeman 1937). However, on much of the overbrowsed range in the Northeast, browse preferences are difficult to demonstrate except for a few notably unpalatable species such as beech *(Fagus grandifolia)* and striped maple *(Acer pensylvanicum)*. And even the least palatable species may not always be rejected. For instance, deer in Pennsylvania have been observed to feed extensively on beech sprouts in the spring while the shoots are young and succulent. Generally, the native conifers are less nutritious than most hardwood species, and serve mostly as "fillers" or "stuffing" during winter browse shortages (Latham 1950).

Browsing intensity does not have a uniform effect on all species. For example, sugar maple *(Acer saccharum)* and red maple *(A. rubrum)* are considered tolerant to heavy browsing, while black oak *(Quercus velutina)* and red oak *(Q. rubra)* are extremely intolerant (Stoeckeler *et al.* 1957, Webb *et al.* 1956, and Sharp 1957). However, where browsing has been severe, even the most tolerant species recover very slowly and often become stunted and malformed (Stoeckeler *et al.* 1957). Obviously this is not conducive to sustained timber production.

The true nature and quality of deer browse may be seriously underestimated. In studying the rumen contents of deer, Bissel (1959) concluded that "deer either select vegetation which is approximately 2 to 3 times higher in protein than is generally supposed," or "the protein content of the rumen is enhanced to a very high degree by some factors not now apparent." The inference here is that considerable research is needed before management specifications can be formulated regarding browse nutrition, palatability, and preference. Dahlberg and Guettinger (1956) summarized the problem when they stated: "Both the habitat and the deer are a lot tougher than we sometimes dare to believe." This fact seems to be substantiated in nutritional studies by Severinghaus (1951) in the Northeast and Goodrum and Reid (1958) in the South, who have shown that a relatively large number of deer (1 deer per 9.5 acres) can sustain themselves for several years on heavily browsed range. However, fawn production declines in advance of any appreciable browsing on low-choice plants.

Browse Measurement

Since one of the major limiting factors in deer management is the extent to which winter range can support deer, one of the basic problems of management is to determine the carrying capacity of the winter range. The purpose of any range inventory is to determine the welfare of existing vegetation in relation to deer-browse production (Dahlbert and Guettinger 1956).

Dasmann (1948) reviewed western range-survey methods and their application to deer-range management. Most of the methods were concerned chiefly with browse or forage species for domestic livestock. The growth pattern of these species generally is different from that of hardwood deer-browse plants. Nevertheless certain principles hold true for all range surveys. Dasmann pointed out that "The range manager needs to be concerned not so much with the fraction that range animals take as with the fraction of vegetative growth that range animals leave." This axiom seems equally appropriate to hardwood deer-browse management. Dasmann called the fraction that animals leave "the range management reserve."

For most management and experimental purposes the ideal browse measurement method should be economically feasible, not too time-consuming, should require a minimum amount of training of personnel, and should yield data that can be tested statistically.

Characteristics of Browsed Twigs

Browse utilization and its effects are not always limited to current annual growth (Aldous, S. E., 1952; Aldous, C. M., 1945). When a twig is browsed, it dies back to a lateral bud or to the previous year's terminal-bud scar (fig. 8). Resprouting will often occur from a lateral bud during the growing season if browsing was not too severe (fig. 9). Repeated browsing of the same twigs during a growing season causes them to become bushy (fig. 10); the mass effect of such severe browsing on a sprout clump is to cause it to "hedge" (fig. 11).

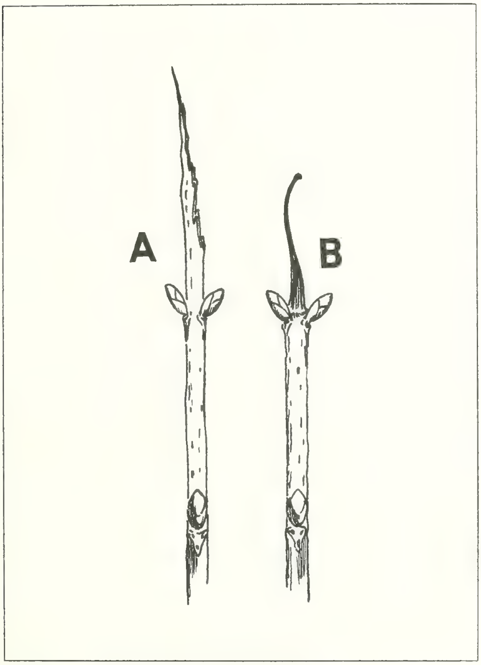

Figure 8.—Effect of deer browsing on twig dieback: *A*, a freshly browsed twig. *B*, a succulent twig that has withered back to a lateral bud after browsing. Hardened twigs browsed in late fall or winter do not wither, but also die back to a bud.

Statistical Considerations

In sampling browse, a limited number of species that are common in the area and preferred by deer are usually designated as the key browse species. This singling out of a few species for intensive study is a matter of practical necessity, and is a standard technique of browse investigators (Julander 1937, Leopold *et al.* 1951, and Cole 1959).

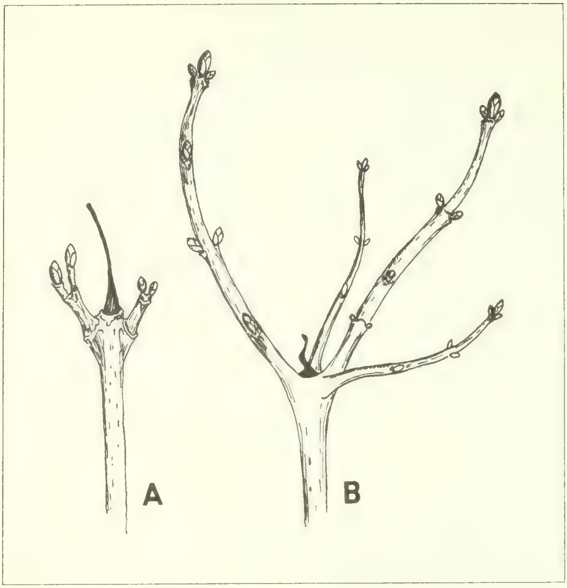

Figure 9. — Re-sprouting from lateral buds after terminal bud has been browsed: A, browsed late in the growing season. B, browsed early in the growing season.

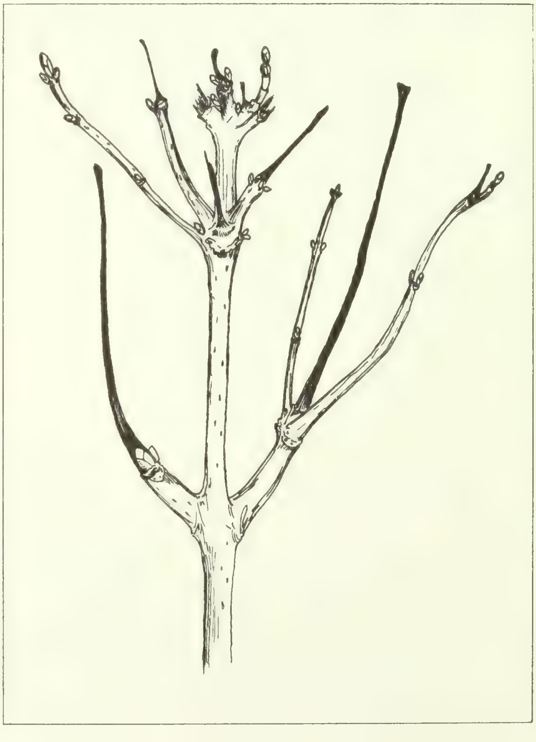

Figure 10. — Heavily browsed twig that has sprouted after each of several browsings during the growing season.

Carrying capacity may vary widely from year to year, which makes it difficult to determine overutilization of large and highly variable ranges. Lauckhart (1955) therefore suggested that browse plots be examined every 4 or 5 years rather than every year.

Snedecor (1957) has pointed out the difficulties involved when a perennial crop (such as browse) is investigated in a statistically-designed experiment that is continued several years on the same plots. He stated that "The yields from a plot in successive years are probably correlated; the experimental error one season is not independent of that in another season." For these reasons, any primary analysis of browse-measurement data from such plots should be based on the sum of plot yields over all the years of the experiment. Cochran (1937) has provided an example for analyzing this type of data.

The shape and size of plot used to sample browse will be influenced by browse density. For example, smaller sample plots would be required in a dense understory than in an open area with sparse vegetation. Two kinds of circular plots are commonly used for browse investigations: the milacre (radius 3.72 feet), and the 100-square-foot plot (radius 5.64 feet). "With the 100-square-foot plot, multiplying grams of browse per plot by 0.96 converts grams per plot to pounds per acre" (Schwan and Swift 1941).

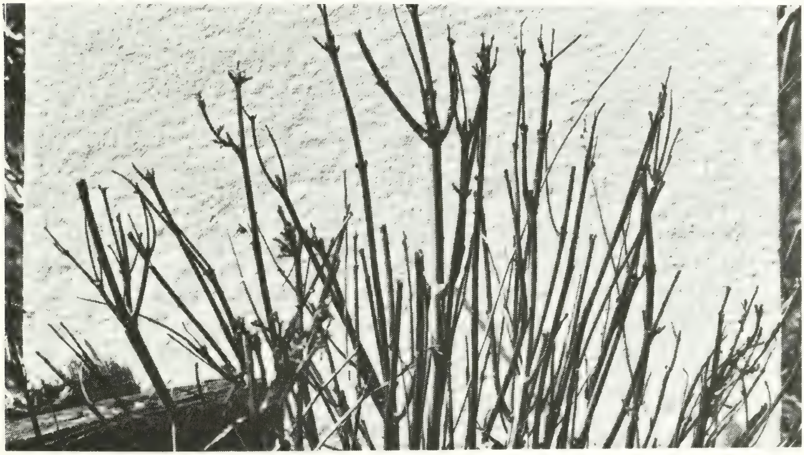

Figure 11.—Severe deer browsing of sprout growth causes it to "hedge".

The number of plots needed to obtain a reliable sample from any area is not primarily a function of the size of the area, but rather of the variation from place to place within it. Bormann (1953) described a method whereby statistical variance can be used to determine the most effective size and shape of plot for sampling a natural plant population. He explained that "Variance (among plots) decreases as plots are increased in length provided that the longest axes of the rectangular plots cross observed contours and vegetational or soil bandings."

Great variation is typical of browse vegetation (Shafer 1961), and the manner in which a particular sampling unit is defined can either simplify or reduce this variation. To determine the total number of plots needed, it is necessary first to establish and measure about 30 plots on the area to be sampled (State of California 1957) to obtain an estimate of the population variance. The resulting data should be analyzed statistically (Snedecor 1957) to learn the degree of reliability attained. The State of California (1957) recommended that browse sampling on deer-management areas should be intensive enough to provide confidence limits of ±10 percent at the 95-percent probability level. It is questionable that this degree of accuracy is necessary in measuring browse production in the Northeast. Size of the deer herd cannot be regulated accurately enough for a change of ±10 percent in browse production to be detected. An accuracy of ±20 percent seems more realistic for Northeastern conditions. A complete randomized design (Shafer 1961) or a mechanical design (Swift 1948) can be used to locate plots.

Other statistical considerations and problems involved in sampling browse have been discussed by Ehrenreich (1958) Evans (1958), and Morriss (1958).

Twig-Length Method

Some wildlife managers determine or estimate the average normal length of twigs or leaders and the average length left after browsing, and then express deer use as a percentage of normal twig length.

Using this method to estimate amount of current twig growth grazed on bitterbrush, Hormay (1943) established plots 20 inches wide and 2 or 3 chains long, which included 20 to 25 average-size plants per plot. Twenty to 25 such plots were recommended in stands of 20-percent density. Hubbard and Dunaway (1958) found that an unrestricted random sample of 19 to 39 leaders from each of five bitterbrush plants studied were required for estimating the true mean leader length within 10 percent of the actual value. This twig-length method can probably be applied to the dormant twigs of other browse species on which current twig growth is easily recognized (Aldous, C. M., 1945; and Aldous, S. E. 1952).

In Montana, Cole (1959) used a "closest-plant" sampling technique to obtain yearly condition and use data from key browse plants. Plant condition was estimated according to browse availability and age classes. Leader-use estimates were expressed as an average based on the percent of total available leaders showing use. Cole recommended sampling about 25 browse plants within each sampling unit.

Julander (1937) measured all current shoot growth before and after browsing on an unspecified number of plots to determine annual utilization of browse in northern Arizona.

In northern and central Wisconsin, 5 million acres were surveyed to determine deer damage to forest reproduction. Eighteen mechanically placed 1/50-acre plots were used to sample each 23,000 acres of managed forest land. Percent browsing was calculated for individual species; damage was rated according to the following categories: unbrowsed, lightly browsed, or heavily browsed. A specimen that had its terminal bud removed or one-third or more of its crown clipped was classified as heavily browsed (Swift 1948).

Twig-Count Methods

In studying seasonal browse preferences, Bramble and Goddard (1953) established 242 plots (1 or 2 milacres in size) in the oak-chestnut forest region of central Pennsylvania, and counted the number of twigs browsed per plot during each month. Each browsed twig was cut with a knife to avoid recounting it the following month. Results were expressed in percentage of total number of twigs utilized by deer.

Eighty milacre plots were sampled by the twig-count method on 238 acres of the Pisgah National Forest in North Carolina to estimate numbers of seedling and sprout stems per acre 2 years after three cutting treatments had been made (Morriss 1954). The topography of the three cutting areas ranged from high cove to ridge top.

When evaluating browse production in clearcuttings of nonmerchantable hardwoods in Michigan, Beale (1960) found that stump sprouts were so small and numerous that complete counts of all twigs on 1/100-acre plots were impractical. Total numbers of twigs per plot therefore were estimated by counting a small subsample in each plot.

Shafer (1961) described a twig-count method for measuring dormant hardwood browse in northeastern Pennsylvania. The method utilized average twig weights to convert twig-count data to pounds of browse per acre.

Density Methods

Density measurements are useful for describing the horizontal aspect of plants and for comparisons of relative spread of vegetation on ranges of similar sites and types. However, Dasmann (1948) has pointed out many weaknesses in density methods, and has recommended that density not be used as a sole measure of browse yield.

In southern Arizona, Cooper (1957) used the variable-plot method, first described by Bitterlich (1948) and Grosenbaugh (1952), to estimate an index of dispersion for shrub cover. This method can be used to estimate densities of shrubs ranging from 6 inches to 30 feet in crown diameter, but is most reliable in open shrub stands of low density. Kinsinger *et al.* (1960) have shown that cover estimates by the variable-plot method are higher than true cover, and they suggest that the method be modified to exclude dead crowns from cover estimates.

Weight-Estimation Methods

Smith (1944) found that weight estimates of browse in three vegetation types (sagebrush, winterfat, and a grass type) in Utah differed significantly among observers on different days and even on the same day. However, Shafer (1961) has shown that the weight-estimation method is almost as accurate as the clip-and-weigh method for measuring browse weight of 2-year-old hardwood sprout growth of various species in the Northeast. The estimation method is not recommended for experimental purposes except by highly trained personnel. Some experienced individuals probably can estimate the weight of browse production almost as accurately as it can be determined by cut-and-weight procedures.

In such cases, estimates can be analyzed statistically and used for experimental purposes, but confidence in these estimates is usually based on some prior knowledge of the correlation between the estimated and actual values—usually as a result of double sampling. For example, Pase and Hurd (1957) used the weight-estimation method, described by Pechanec and Pickford (1937), on twenty 9.6-square-foot plots (for each of 31 sample areas) to estimate herbage production under various basal-area conditions of the ponderosa pine type in South Dakota and Wyoming. But to relate estimates to actual weights, they measured the herbage quantitatively on a square-foot subplot in the center of alternate 9.6-square-foot plots.

Clip-and-Weigh Method

The clip-and-weigh method used in many western range surveys (Schwan and Swift 1941) has not been used so extensively for measuring hardwood browse.

Following aspen logging in lower Michigan, Casey (1954) used 10 milacre plots to measure browse production by weighing twigs clipped at the 1/4- and 1/2-inch diameter points; these two clipping dimensions represented use by deer during normal and high population pressures. Dalke (1941), in an exclosure study in the Ozark plateau of Missouri, and Blair (1960), in a loblolly pine *(Pinus taeda)* thinning study in Louisiana, clipped and weighed all current annual growth (leaves and stems) of herbaceous and woody forage to a height of 5 feet on milacre plots.

Goebel *et al.* (1958) described a "25-square-foot method" used in surveys of desert shrub vegetation on relatively small areas. Forage production by each species was derived by determining the average air-dry weight per 1/16-square-foot unit of the species, and multiplying by the number of such units that the species occupied. The average weights were determined by clipping, drying, and weighing samples of the current year's growth of each species.

Descriptive Methods

McConnell and Dalke (1960) used a qualitative approach for range evaluation in Idaho by noting the general relationship of vegetation to the browsing habits of deer. Dahlberg and Guettinger (1956) also used this technique in a random walking cruise (or appraisal) of a large number of deeryards in Wisconsin.

Observers made notes on species distribution, composition, and density, availability of various deer-browse plants, evidence of current browsing pressure, and the degree of yarding. Although reports of this type are somewhat subject to human error, they were considered to be sufficiently accurate for use in formulating deer-management recommendations in Wisconsin.

Comparison Method

Roy (1960) studied set-back caused by deer browsing on Douglas-fir seedlings *(Pseudotsuga menziesii)* in northwestern California. Two curves were compared: one curve showed average heights by years through the first 6 years after planting for seedlings that were not browsed or were browsed only once; the other curve showed average 6-year heights of seedlings under different frequencies of browsing. The range in average 6-year heights was 16 to 41 inches. Thus trees that were browsed every year were set back 25 inches.

Pellet-Conversion Method

Leopold *et al.* (1951) used a pellet conversion method in estimating forage use on the Jawbone range in California. They made no actual weight determinations of forage produced or utilized, but on the basis of figures worked out by Nichol (1938), Smith (1950), and others, they computed from pellet counts the approximate amount of forage removed per acre. These computed estimates corresponded fairly well with Leopold's impression of changing forage density in the study area.

Exclosures

Exclosures with check plots immediately adjacent have been used in many places to study the effects of browsing on the vegetation (Grisez 1959, Stoeckeler *et al.* 1957, Krefting and Arend 1960, and Graham 1958). By measuring the amount and types of reproduction that develop when an area is completely protected from deer, in comparison with the growth on an unprotected but otherwise similar area, data are obtained from which evaluations of range condition and browsing pressure can be made.

The following studies were conducted to show the types and amounts of damage and the problems encountered in establishing forest reproduction in areas of excessive deer populations:

1. In oak-maple stands in northeastern Pennsylvania, Shafer *et al.* (1961) enumerated and measured the height of all vegetation in six 1/40-acre exclosures and associated check plots.

2. In the Adirondacks, Webb *et al.* (1956) studied the results of protection in two 2.1-acre fenced areas in a mature northern hardwood stand. Their data were based on 24 3-foot-square sample plots in each exclosure and in each adjacent check area.

3. Livestock and deer were excluded for 10 years from a series of three 0.1-acre plots in each of three major timber types in the Arkansas Ozarks (Halls and Crawford 1960). The estimation method was used on ten 3.1-foot square plots inside and outside each exclosure to determine the weight of browse and herbage produced up to a height of 5 feet.

Two experiments by Dahlberg and Guettinger (1956) in Wisconsin provided demonstrations of range-carrying capacity, which have been used to help laymen understand the relationship between deer and their habitat. In the first experiment fenced exclosures were established to compare shrub and tree growth in protected and unprotected areas. In the second experiment, fenced enclosures were used to confine a known number of deer to specific units of range. The number of deer-browse days in different enclosures was varied to show the effects of different degrees of browsing pressure on the range.

The effects of cattle grazing upon sprout growth of tamarisk *(Tamarix pentandra)* were computed in Arizona by using three fenced plots and three unfenced plots (Gray 1960). Within each plot 75 tamarisk plants were cut about 6 inches above ground. Then, at monthly intervals, the sprout growth was clipped from 10 randomly selected cut plants in each plot. New plants were selected for each monthly sampling.

In Minnesota, Aldous (1952) conducted a clipping study on northern white-cedar *(Thuja occidentalis)* and several hardwood species in exclosures to obtain information about how much deer browsing these species could withstand and still continue to grow.

Cooley (1961) has shown that the fence need be only 4 feet high for exclosures of 1 milacre. For larger exclosures, 10-foot fencing is recommended. Exclosures of 1 acre or more involve excessive maintenance costs (Dahlberg and Guettinger 1956).

Conclusions

Although results of the studies that have been reported are somewhat variable because of different research procedures and the wide range of browse conditions, several generalizations concerning the production, utilization, and measurement of hardwood browse can be made:

- Management of forest land for browse production usually should be integrated into multiple-use land management in which sustained timber production is one of the other uses, except possibly on submarginal forest lands.
- Commercial timber cutting according to either group selection or shelterwood silvicultural systems, with 10- to 20-year cutting cycles, is adaptable to sustained timber-browse production in the Northeast.
- Silvicultural thinnings in pole-size hardwood stands provide maximum available browse, increase timber production, and yield a higher return on the investment than other cultural operations.
- Deer herds should be balanced with or reduced below the existing carrying capacity of the range before browse management is attempted.
- Browse cuttings should be aimed at creating a wide variety of age classes, densities, and species mixtures in the woody vegetation.
- Since, within any large area, some localized portions are likely to be relatively overstocked or understocked, browse management on the area as a whole should be based on average conditions.
- Browse production on winter deer range should be in balance with use of the range by the animals.
- Noncommercial browse-production methods include the cut-and-bend method, aerial and ground applications of herbicides, fire, and bulldozing. The cut-and-bend method is appropriate for commercial thinning operations if maximum browse production is desired.
- Sprouting ability of hardwood stumps declines sharply with tree age and with size after a stem d.b.h. of 8 to 10 inches is attained.

- Browse grows more slowly under partial canopy or under slash than in the open.
- Deer tend to select the available twigs of certain species that are highest in nutrient content. How they are able to select nutritionally superior browse is not known.
- Protein content of deciduous browse is greatest during the growing period and declines gradually as the tissues mature and become dormant, reaching a minimum in winter.
- Some species are more tolerant to browsing than others, but even the most tolerant species recover very slowly after repeated severe browsing.
- Deer are very adaptable and can alter their food preferences according to the browse species that are available.
- Great variation in the woody browse vegetation within areas and between areas is typical, and consequently measurement is difficult. Many methods have been used to measure browse production and utilization. Those that express quantities of browse in pounds per acre seem most realistic for management purposes.

The final conclusions from this review are that browse production, utilization, and measurement are subjects that (1) offer unlimited research possibilities, and (2) merit intensive research because of the increasing emphasis on multiple-use of forest lands.

Research Needs

Following is a list of studies, which are comprehensive in scope and will require major research to obtain adequate answers to the problems involved. These studies, arranged in a tentative order of priority, are considered to be of primary importance.

- Develop browse-measurement techniques that are quick and easy to use and that are sufficiently accurate for both research and management purposes.
- Determine the kind and size of experimental designs necessary for sound results in multiple-use research on deer browse and timber production.
- Determine the effects of various timber-stand-improvement practices, commercial cutting intensities, and silvicultural sys-

tems (including coppice management) on browse production and utilization, and on timber growth and quality, in the major forest types and conditions of the Northeast.

- Determine how best to integrate noncommercial browse-production techniques such as fire and bulldozing with sustained timber production.

In conjunction with or paralleling these last two items:

- Investigate the minimum daily and seasonal nutritional requirements of deer.
- Determine the basis of palatability and preference in browse, and how variations in nutrient content associated with species, origin, age, and condition of browse affect palatability and preference.
- Explore the effects of various browsing intensities on nutrient content and future growth potential of both sprouts and seedlings of important timber species of the Northeast.
- Investigate fertilization treatments for increasing the nutrient content and palatability of those species in the understory that are both low-preference deer food and of low value for timber.
- Study the nutrient content, palatability, and preference (1) of twigs growing in various sections of the crowns of felled trees, and (2) of twigs growing from the root collars and stumps of various species under different overstory density and site conditions.
- Determine the amount of woody browse consumed in relation to amounts and availability of other foods such as mast and herbaceous plants.
- Study the net effect on other wildlife of maintaining a deer population in balance with the carrying capacity of the range.

■

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The SURFACE GEOMETRY of a closed conifer forest

in relation to losses of intercepted snow

by *Donald R. Satterlund*
and *Arthur R. Eschner*

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The
SURFACE GEOMETRY
# of a closed conifer forest

in relation to losses
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■

This paper is a contribution from the Cooperative Watershed-Management Research Unit, New York State University College of Forestry, and U. S. Forest Service, Northeastern Forest Experiment Station, Syracuse, New York.

INTRODUCTION

FROM snow studies too numerous to mention there is general agreement that much of the snow that accumulates on conifer forests is evaporated into the air and thus never contributes to water yields. Quantitative estimates vary widely, from 9 inches water equivalent for some seasons at the Upper Columbia and Williamette Basin Snow Laboratories (U. S. Army 1956) to negligible in other areas, depending upon vegetative density, quantity and frequency of snowfall, and many other factors.

Miller (1961), after a thought-provoking analysis of 110 investigations, suggests that snow research may be a victim of "technical folklore," and that snowfall interception may be grossly exaggerated. He questioned both the accuracy of snow measurements and the availability of energy required for snow evaporation.

The objective of the following analysis is to examine the process of snow interception in light of the involvement of geophysical and climatological processes within the peculiar geometry of snow held aloft by a conifer canopy, in contrast to the same processes acting on a snowfield on open, level ground. Perhaps an analytical contribution of this kind will stimulate research that will lead to a better understanding of snow interception, and ultimately to application in forest-land management for water yield.

ENERGY SOURCES FOR EVAPORATING SNOW

Because snow-interception losses involve evaporation to the atmosphere, and evaporation requires energy (more than 600 calories per gram of snow converted to water vapor) we must first consider the sources of this energy. They are essentially three: (1) the originating source, solar radiation; and the secondary sources, (2) long-wave radiation and (3) advected sensible heat.

Solar Radiation

Solar radiation may supply considerable quantities of heat. For instance, prior to the melt season of 1946 in the Sierra Nevada up to an average of 350 langleys was received daily, and during the melt season in April and May, 650 to 700 langleys (Miller 1950). The latter values were associated with a net radiation balance of about 100-200 langleys daily, which would cause evaporation of 0.2 to 0.4 grams of snow per square centimeter if all were used in evaporation. However, much is often used for melting snow. Yet even 0.15 grams of snow per square centimeter evaporating daily amounts to 1.77 inches per month, certainly not a small amount.

The impact of solar radiation on intercepted snow in a closed conifer stand may be quite different than on an open snow-covered area. The irregular topography of the intercepted snowfall results in concentration, dispersion, and shading of the solar radiation. The approximate pattern of direct-beam radiation can be deduced from a simplified model of a conifer crown as a cone, and a stand as a series of cones overlapping at the base. Taking any given conditions of spacing, mean height of upper crown closure, and height of crown tip above level of closure, and height, diameter, and thus slope of the cone surface can be defined. Dividing the cone surface into eight aspects permits calculation of the approximate quantity or proportion of the direct-beam radiation received at any given time on each slope and aspect, by means of procedures outlined in Fons *et al.* (1960). In a closed stand, the area of shadow would also require determination.

In this geometrical situation the implications of the concentration of radiation to snow evaporation, especially under conditions of prevailing air temperatures below freezing, are clear. Where radiation is intense on the snow surfaces, strong vapor pressure gradients could develop from snow to air, causing considerable evaporation; whereas, if radiation were dispersed over a level snowpack, the same quantity of radiation per acre might be insufficient to cause evaporation. Qualitative evidence of this phenomenon has been observed by the authors on days when the maximum air temperature did not exceed 20° F., in late December when direct-beam radiation was at its weakest.

Albedo

However, the intensity of incoming radiation at any given point on a snowfield is not a direct measure of the energy absorbed. A portion of the radiation is always reflected; the proportion is the albedo of the snowfield. The amount absorbed is the complement of the albedo, and absorption is the significant element of the snowpack radiation balance, for only energy absorbed can contribute to melt, evaporation, or heating of snow. For example, an albedo change from 90 percent to 80 percent is only an 11-percent reduction in reflection, but it represents a 100-percent increase in absorption. This distinction should be kept clearly in mind when assessing the significance of albedo, particularly where high albedos are involved.

The albedo of an intercepted snowfield, in contrast to that of a snowfield on open ground, is strongly influenced by the opportunities for multiple reflection. For instance, where snow is essentially continuous over a conifer canopy, escape of reflected radiation would be at its maximum, but reduced to the extent that some is reflected to snow on the sides of adjacent trees. When snow is discontinuous, a far more common situation, considerable reflection to the underside of snow-covered branches and into the snowless portions of the trees occurs. Thus an albedo of 90 percent, measured in the open, may be reduced in the intercepted snowfield by multiple reflection to 81 or 73 percent, or less, and almost completely if reflected onto snow-free surfaces. Absorption is, commensurately, 10, 19, or 27 percent or more in the canopy snowfield.

The fact that the depth of the intercepted snowfield is generally much shallower than depth in the open will also reduce the albedo. Kuzmin (1956) indicated that the albedo of a continuous cover of snow at the beginning of a period of melt (not throughout the period) decreased from 82 to 60 percent as the depth of the snow varied from 80 to 5 cm.; the latter figure a fairly representative depth of intercepted snow, the former a reasonable snowpack depth in many areas. The amount of radiation absorbed by the thinner snow is more than double that of the thicker layer, even though albedos differ by only 22 percent.

The major reason for initial differences in albedo of snow similar in all respects except depth is that snow reflects radiation not only from the surface, but also from underlying layers (Kuzmin 1956). It is well known that snow transmits considerable quantities of radiation: as much as 50 percent of the radiation that penetrates the surface may reach a depth of 10 cm., and 10 percent may reach a depth of 30 cm. (Geiger 1959). Molchanov (1960) indicated that a snow layer 3 cm. thick, and having a density of 0.16, transmitted about 32 percent of the incident solar radiation, but a layer of 35 cm. of snow let through only 1.5 percent. In a deep snowpack, only part of this attenuation would be due to absorption; the other part would be due to internal reflection that escapes from the snowpack. If we consider an intercepted "snowfield," shallow in depth and overlying dark coniferous foliage of low albedo, it becomes clear why the thin "snowfield" has a lower albedo than the thicker one.

The effect of thickness of the intercepted "snowfield" on the quantity of incoming radiation absorbed is not limited to initial differences in radiation absorption as developed above. An intercepted snowfield 5 cm. deep and having a density of 20 percent has a mass of 1 g./cm.^{2} With a specific heat of 0.5 cal./g., net absorption of only 0.5 cal. would provide enough energy to raise the temperature of this thin snowpack by 1°C. A deeper snowpack on the ground absorbs radiant energy through a greater depth, and therefore a smaller portion is absorbed in the upper 5 cm. layer, so it heats more slowly. Since a very thin layer of water normally covers ice or exists in snow crystals at temperatures somewhat below freezing (Chalmers 1959), the surface of the intercepted "snowfield" becomes wet sooner. The effect of increasing the liquid water content is to reduce albedo, and thus an even greater differential in capturing incident radiation begins, until the final disappearance of the intercepted "snowfield".

Sensible Heat

Sensible heat of the atmosphere appears as a possible important source of energy for snow borne on the canopy of a conifer forest. If the air is warmer than the snow, some of this energy can be transferred by turbulent exchange to the snow. Even if no temperature gradient exists initially, and snow and unsaturated air freely co-exist at the same temperature, nothing can prevent vapor transfer from snow to air as long as a vapor pressure deficit exists in the atmosphere. Energy for the vapor transfer is derived from the entire system; the sublimating snow becomes cooler, a temperature gradient develops between air and snow; and the whole system cools until both temperature and vapor pressure are in equilibrium.

Sverdrup's equations for turbulent heat and vapor transfer to or from a snow surface, as presented by Diamond (1953) are:

$$O = \frac{Cp\ Pk_o^2\ Va\ (t - t_s)}{\ln\ (a/z_o)\ \ln\ (b/z_o)} \qquad [1]$$

$$F = \frac{0.623}{p}\ \frac{Pk_o^2\ Va\ (e - e_s)}{\ln\ (a/z_o)\ \ln\ (b/z_o)} \qquad [2]$$

where O = heat transfer in cal./cm.^{2}/sec.; F = evaporation in g./cm.^{2}/sec. (cm./sec.); Cp = specific heat of air at constant pressure, 0.24 cal./g./°C.; P = density of air, 1.276×10^{-3} g./cm.^{3}

at 1,000 mb. and 0° C.; V_a = wind velocity at height a, cm./sec.; t = air temperature at height b, °C.; t_s = snow surface temperature, °C.; e = vapor pressure of air at t, mb.; e_s = vapor pressure of snow at t_s, mb.; k_o = von Karman's constant, 0.42; z_o = roughness parameter, 0.25 cm. for snow from Sverdrup (1936); p = surface pressure, assumed 1,000 mb.; b = height of temperature and humidity element, assumed 2 m. to approximate height of instruments in shelter; a = height of anemometer, assumed 6 m.

It is assumed in this study by the use of the Sverdrup model that eddy diffusivity of heat and vapor are the same as for momentum transfer. Portman *et al.* (1961) indicate that this relation is reasonable when lapse conditions do not depart too far from the adiabatic, but it is questionable for other lapse conditions. Brooks (1959) suggests that eddy diffusivity may be considerably less under inversion conditions and considerably more under thermal convection.

With these limitations in mind, a review of equations [1] and [2] reveals possibilities for increased turbulent heat transfer to intercepted snow in a forest canopy as contrasted to snow in a level field. It is possible that differences in the measured variables of wind speed, temperature of air and snow, and vapor pressure may exist between a "snowfield" in a canopy and one on open ground.

If the reference elevation from which a and b in equations [1] and [2] are measured is the snow surface in the case of the open, level snowfield, then the reference elevation of the "snowfield" held in the canopy would approximate the elevation of complete crown closure (Baumgartner 1956). How would the above variables be affected when measured above the "snowfield" of the crowns as contrasted to an open, level snowfield?

Wind speed measured at 6 m. above our reference elevation is likely to show some change. Baumgartner (1956) indicates that above a forest of limited extent to windward wind was stronger than in the open, because the higher strong winds from the open were impressed on the layers above the tree tops. When wind was measured after passing over an extended area of forest from another direction, the differences were less. Wind speed, therefore, may be slightly greater over the forest.

Comparative data for temperature and vapor pressure at 2 m. above the reference elevation of a crown "snowfield" and that in the open were not found for winter conditions. It will be assumed that differences are negligible. During all periods when the air temperature equals or exceeds 0° C., it can be assumed that the temperature and vapor pressure of the snow surface in the open field or in the canopy should be the same, as snow cannot assume a temperature in excess of 0° C., and unless a strong inversion is present, it will quickly assume its maximum temperature. When air temperatures are less than 0° C., snow surface temperatures in the crown canopy are likely to slightly exceed those on the ground in the open, for reasons to be discussed later.

With regard to the remaining elements in equation [1]; specific heat of air and von Karman's constant should be the same. Density of air would be only slightly decreased, depending on the height of the stand, and will be assumed negligible. Only the roughness parameter is likely to be substantially different when an intercepted "snowfield" is compared with a snowfield on open, level ground.

Of all the elements in equations [1] and [2] the possible differences in roughness parameter exhibits the most fruitful possibility for explaining increased evaporation from an intercepted "snowfield" in a closed conifer forest as contrasted with a snowfield on level, open ground. It is obtained by plotting wind speed at several elevations above a given surface against height; the curve is extrapolated to zero wind velocity, and the height intercept denotes the roughness parameter of the surface (Light 1941).

Wind velocity in relation to height above a surface follows a power law (Baumgartner 1956, Brooks 1959). By plotting wind speed above a forest canopy during periods of neutral stability, we can determine the roughness parameter for a given closed conifer stand if we can determine a suitable reference surface. If we accept Geiger's (1959) concept of an outer active surface for a forest canopy, we cannot use the ground surface as our zero plane, or the height of the surface above which roughness elements project, for then it would automatically follow that the roughness would be a function of total tree height. Brooks (1959) presents a means whereby the zero plane displacement can be calculated, and above which the roughness parameter would be measured, as does Baumgartner (1956). The zero plane displacement is upward into the approximate level of full crown closure. Using data from a young dense pine plantation in Germany, Baumgartner (1956) calculated a z_0 of 290 cm. Byers (1959, p. 515) presents a formula from which he calculates the roughness parameter:

$$\frac{U_1 = \ln (z_1 + z_0)/z_0}{U_2 = \ln (z_2 + z_0)/z_0} \qquad [3]$$

where U_1 and U_2 = wind speeds at height Z_1 and Z_2, respectively; Z_1 and Z_2 = anemometer height above a given surface; and Z_0 = roughness parameter. He states that with a park-like distribution of trees, Z_0 is about 100 cm., but the source of his data is not given.

Rough calculations by the authors from wind speeds above and in the crown space of two 65-year-old Scots pine stands (data from Geiger 1959) and a 50-year-old dense ponderosa pine stand (data from Fons 1940) by the graphical method and equation [3], using assumed zero plane displacements, yielded a range in roughness parameters from 30 to 175 cm., with a mean of about 80 cm. However, these figures are probably conservative, as the anemometer placement did not extend more than 3 m. above the stands in any case, and a true free-air profile was not ascertained. Estimates of roughness parameters therefore range from 30 to 290 cm., a surprisingly broad range, considering that the latter is associated with the most uniform crown canopy. For a level open snowfield, Sverdrup (1936) gave a roughness parameter of 0.25 cm. and Geiger (1959) a figure of 0.5.

From equation [1] we can estimate the effect of changing roughness parameters by letting the numerator = K, a constant for any given air mass and snow surface temperature.

Completing the equation with z_0 = 0.50 cm. for a smooth snowfield, we get heat transfer to or from it in the quantity K/43.03816. If we choose a roughness parameter for the forest of 100 cm., heat transfer to the intercepted snowfield equals K/1.24195, or nearly 35 times that to the snowfield on open level ground. If we choose the lowest roughness parameter, 30 cm., our equation reduces to K/5.68475, or about 7.5 times the heat transfer to an open level snowfield. Any forest parameter greater than 200 cm. gives a nonsense answer of heat transfer against the temperature gradient. Either the roughness parameter of 2 m. is too great, or equation [1] is invalid for such high roughness, or both.

Thus the effect of surface roughness can be substantial, if the other elements of the equation remain constant. However, it is difficult to conceive that initial temperature gradients between air and snow could long continue to exist under such conditions of high wind and roughness parameter. Wilson (1941), assuming a value of 700 m. for the thickness of the turbulent layer, 0.0012 for air density, and a heat loss of 10 cal./cm.^{2}/hr., has calculated the loss of heat in an air mass moving 10 m. per second as about 0.5° C. in 25 miles over snow. Unless a snow-covered area were near a heat source, such as the sea, or on a lee mountain slope subject to adiabatic warming, the temperature of the air mass would soon drop to a level in which no amount of turbulent action could transfer appreciable sensible heat (Miller 1963, personal communication).

Even if the constant, K, were positive (indicating heat transfer to snow) rather than negative (indicating heat transfer from snow), as the net of accumulated advective heat transfer for the snow season should be in mid-latitude locations, it is obvious that turbulent heat transfer from air to snow would account for large interception losses only if the energy were used for evaporation rather than melt.

The vapor transfer equation [2] is analogous to equation [1] for heat transfer, but whether condensation (with or without melt) or evaporation occurs is dependent upon how the vapor pressure gradient is synchronized with the temperature gradient. In moist maritime air, evaporation is not likely; but evaporation situations can be found in the Chinook of the West and weakly in the subsiding air following the passage of a cold front.

Muller (1961) has calculated net snow evaporation for an open field at Syracuse, N. Y., for February 1961. Mean daily temperature ranged from −7° F. to 47° F. Evaporation occurred for 521 hours during the month, and condensation 151 hours. Net evaporation occurred on 23 of the 28 days and amounted to 0.296 inches of water equivalent. During this period, there were only 294 hours of possible solar radiation. Further, condensation occurred for only a maximum of 100 hours during 378 hours of nocturnal conditions. If this month is typical, then atmospheric conditions suitable for turbulent heat transfer to snow synchronized with vapor transfer from snow must be present nearly one-half the time, neglecting entirely the possibility of a warmer snow surface temperature from solar radiation as a cause of evaporation. It should be pointed out, however, that a weak foehn occurs at Syracuse (elevation about 400 feet) whenever the wind direction has southerly component, from whence elevations approximate 1,200 to 2,000 feet within 20 miles; but these conditions are common throughout much of the Northeast. These data suggest that, had snow been in a conifer canopy during this entire period, interception losses could have reached 2 or more inches water equivalent.

Persistence of Snow in a Conifer Canopy

Obviously snow does not persist continuously in a conifer canopy. Observations by Lull and Rushmore (1961) in the northern Adirondacks indicated that snow was present in various amounts on branches, nailed at a height of 5 feet on a wooden post, two-thirds of the time from December 8, 1959, to March 22, 1960. Wind velocities in the upper canopy of a stand might easily be higher than at the point of observation, reducing this — by blow-off and increased rates of evaporation and/or melt — by an unknown amount.

Twenty-two systematic observations by the authors from November 30, 1961, to April 27, 1962, at Tully Forest, New York, revealed intercepted snow in the tree crowns 63.6 percent of the time. The entire winter was deficient in quantity and frequency of snowfall, with only one snowfall in the entire month of March.

It seems reasonable that snow in central and northern New York may be available for interception loss for one-half the period of observation, during which snow on the ground is continuously present. Kittredge (1953) indicates similar relative persistence of intercepted snow in the Sierra Nevada Mountains.

Considering that the increased magnitude of energy supplied by turbulent transfer of heat from air to snow considerably exceeds the reduction in availability of snow for evaporation from a closed conifer stand as contrasted with a snowpack on level, open ground, we may conclude that the surface geometry of the conifer stand, expressing its effect on the roughness parameter, is sufficient to account for considerably higher losses from an intercepted "snowfield".

The above assumes that wind speed above and snow surface temperatures on the intercepted "snowfield" are the same as those on open, level ground. Both, however, are probably somewhat higher in the canopy, which would increase intercepted losses in relation to losses from an open, level snowpack. The explanation for increased wind speeds was given previously, but the increased temperature requires explanation.

A forest canopy, located at a greater or lesser distance above the ground, is always more or less porous, even where most of it is covered with snow. Theoretically, this should affect the formation of any inversion layer to a different degree than would occur above a snowpack on level, open ground. Air that is cooled in contact with cold snow becomes more dense. On the ground, it can only stagnate and build up a strong, if shallow, inversion. In the canopy, however, this cool air can sink through the porous layer, being replaced with slightly warmer air. Or, it can flow off the canopy into surrounding open areas. Geiger (1959) mentions a distinct forest breeze, detectable at a considerable distance from the forest edge, during a calm night with strong outgoing radiation. The subsiding air could possibly add small quantities of heat to the snow on the canopy, thus maintaining a slightly higher temperature, while lower temperatures are created on the snow in the open. A practical application of this phenomenon is being tested to increase the persistence of the snowpack in clearcut areas in the forest snow zone of California (Anderson 1963).

Long-Wave Radiation in the Canopy

Not all radiation absorbed is available for evaporation of melt in snow. All bodies continuously radiate heat, according to the Stefan-Boltzmann law, in an amount proportional to the 4th power of their absolute temperature. Little difference should exist in absorption of atmospheric or cloud long-wave radiation between the two snowfields considered, for snow is essentially a black body to most long-wave radiation and the difference in albedo would be negligible. Similarly, during periods when the air temperature is 0° C. or above, both should radiate at the same rate per unit area, as snow cannot attain a temperature higher than 0° C.

When air temperatures are less than 0° C., on clear nights and under conditions of incoming solar radiation, intercepted snow should radiate at a slightly greater rate than snow in an open, level field, because of the higher temperature of the snow surface indicated previously. The mean increase in the temperature of the intercepted snow is unknown, so the increase in outgoing radiation can only be surmised.

Snow as an Energy Storage Factor

The capacity of snow to store energy as sensible heat has been referred to in the discussion of the effect of thickness on the albedo of the contrasting snowfields. Another factor that influences the disposition of absorbed energy is the capacity of the snow to retain liquid water, and the disposition of melt water not retained in the snowpack.

Melting and evaporation of snow can occur over a surprisingly broad range of temperatures (Diamond 1953, Chalmers 1959). If liquid water is retained in the snow, only to refreeze later, melting represents a heat sink with a capacity of 80 cal./g. (the latent heat of fusion of water), while freezing represents a heat source of the same capacity. A thin snowpack held in the crown canopy of our closed conifer forest would be unlikely to retain more than 10 percent of its original water equivalent, considering that the melt process in itself reduces the depth of the snow. For a snowpack of 1 $g./cm.^2$, this would amount to only 0.1 g., the melting of which, and later refreezing, would convert only 8 calories of heat. On the other hand, a deep snowpack could not only retain a considerably greater quantity of water, but by gravity drainage could distribute it throughout the snowpack.

This differential in the two contrasted snowfields is important, for it is possible to carry over energy received during periods of incoming energy that is available as a source of energy for evaporation or outgoing long-wave radiation at night. Energy so carried over and lost to outgoing radiation is obviously not available for evaporation and must be deducted from incoming energy to obtain the amount available. Miller (1950) has estimated that the carry-over may represent 100 langleys daily in the snowpack on the ground in the Sierra Nevada mountains in early May.

A major implication of the limited capacity of intercepted snow as a heat sink may be of considerable importance in causing evaporative losses. If the carry-over energy capacity is only a small quantity, such as 8 or 10 $cal./cm.^2$, then only very short periods of a positive radiation balance will result in snow evaporation and/or melt — especially considering that intercepted snow is often held in positions more normal to the sun's rays than snow on open ground. The larger heat sink represented by deeper snow on the open ground would require a much longer period of radiation surplus before similar evaporative conditions are developed.

For example, assume an albedo of 70 percent for each snowfield; a heat-sink capacity of 10 $cal./cm.^2$ for snow in the crown and 50 calories for snow in the open; and consider that the snow in the crown is oriented from 0° to S 45°, while that in the open is horizontal (0°). Calculations of the approximate direct-beam radiation absorbed in the two snowfields between 11:00 a.m. and

1:00 p.m. on an average clear day in December at latitude 42° N. range between 11 (0° slope) and 26 (S 45° slope) cal./cm.[2] This would provide a surplus of up to 16 calories available to evaporate exposed snow in much of the crown and none in the snowpack in the open. The daily radiation balance would be negative.

This small difference, accumulated over the snow season, could prove substantial. Therefore the capacity of snow as a heat sink may be critical in determining the length of the period of radiation necessary to cause snow evaporation. A daily radiation balance may be sufficiently accurate to account for losses from a deep snowpack on open ground, but frequently misleading if used to account for losses from intercepted snow.

Consideration of melt water not retained in the snowfield further increases the disparity in evaporative losses within a forest canopy and on snow-covered open ground. Except during the final stages of disappearance of the snowpack on the ground in spring, most melt water drains into the soil or at least below the snowpack. It becomes essentially unavailable for evaporation, for to get evaporation, energy must be applied to the water, which is protected by the snowpack above. If snow in the crown begins to melt at a rate exceeding the "snowfield" storage capacity, drip begins. Miller (1955) mentions that drip is exceedingly common in the Sierra Nevada, but observations by the authors in central New York indicate that while drip is not exceptionally rare, neither is it common. This drip often wets much of the crowns of trees, and maintains them in a wet condition for long periods. The wet surface reduces the albedo of the crowns; liquid water films may warm considerably — thus breaking the 6.11 mb. vapor pressure barrier of snow — and evaporate under conditions that may result in condensation on snow in the open.

During advection melts, air temperatures are often relatively high. Heat is available and considerable evaporation from tree crowns must occur in many instances, if only from the intercepted drip. If radiation melt occurs during clear weather and freezing temperatures, evaporation from melt water in tree crowns might even be greater. The combined evaporation from snow and retained melt water in the forest canopy may exceed evaporative losses from a snowpack on level ground even more than during non-freezing periods. Goodell (1959) measured the loss of snow from a severed branch suspended on scales in full sunlight at Fraser, Colorado. Air temperature ranged from −7° to +5° C., the dewpoint was −14° C., and there was little wind. In just 2 hours and 40 minutes, 128 grams of snow were lost by evaporation and sublimation. Melt, but no drip, occurred. These data are sufficient to indicate that intercepted snow can be lost rapidly.

Canopy Coverage as a Factor in Evaporation of Intercepted Snow

The pattern of incident radiation, differences in albedo, thickness, capacity for heat storage, and disposition of melt water, all tend to accelerate the rate of exposure of bare crown canopies following snowfall, whereas snowfields on the ground remain essentially continuous throughout the snow season.

As more and more bare foliage appears, more solar radiation is absorbed, with consequent increased foliage temperature above ambient air temperature. Ehlers (1915) indicated that needle temperatures may exceed air temperatures by as much as 9° C. on a clear winter day in Ann Arbor, Mich. (latitude 42.5° N.). Sensible heat transfer by advection and convection, and long wave radiation, could provide appreciable additional energy to snow patches that remain. As the amount of snow cover decreases, the rate of heat transfer, and thus evaporation and/or melt of intercepted snow, should increase until it finally disappears. This process, frequently repeated in the forest canopy, would be largely inoperative during most of the snowpack season in an open, level field.

DISCUSSION AND CONCLUSIONS

All factors considered, there seem to be great differences in the energy and vapor balance between an intercepted "snowfield" and one on level, open ground which appear to result from the complex surface geometry of a closed conifer forest. There is little question that these differences are sufficient to account for considerably greater losses from intercepted snow. It would be tempting to present a quantitative comparison of the water balance between the two contrasting situations, but too few data are available, and interactions are too complex to provide other than speculation.

Despite the limitations in the assumptions, lack of data, and ignorance of energy transfer in complex situations, this analysis has revealed areas that should receive greater cognizance in snow-interception studies. Many problems of advection and turbulent heat transfer to snow in a forest canopy have received scant attention. The potential water losses attributable to this energy source are sufficient to deserve more intensive investigation.

Radiative heat fluxes are better understood and have received wide attention, but under the complex situation of snow in a forest canopy much remains to be done. Questions of depth, location, and persistence of intercepted snow, canopy exposure, structure, and storage capacity are little known but clearly pertinent to our quest. And rigorous means of characterizing forests in relation to these factors are largely lacking.

The classical type of snow-interception study, whereby snow is measured on the ground under different types and densities of vegetation, has yielded much useful information. For continued yield of new knowledge, however, such studies have probably passed the point of diminishing returns under most forest conditions. Snow losses should be studied where they occur — in the trees themselves. Combined with the classical interception study to serve as a quantitative check, a better understanding of the process of snow interception should result.

This qualitative analysis of the loss process suggests that snow interception losses may not be so grossly exaggerated as they appear to be.

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GARY R. LINDELL took his Bachelor's degree in forestry at the University of Minnesota in 1960 and his Master's degree in forest economics in 1962. At the time the study reported here was made, he was serving on the research staff of the Northeastern Forest Experiment Station's Forest Products Marketing Laboratory at Princeton, West Virginia. Recently he transferred to the Lake States Forest Experiment Station at Duluth, Minnesota, and is currently working toward a Ph.D. in forest economics at the University of Michigan.

Problems in Marketing

LUMBER producers in West Virginia have some common problems in marketing the lumber they produce: what type of lumber to produce; where to sell it, and when, and how. Their marketing problem is complicated by the fact that most of the lumber they produce is sold to wood-products manufacturers in other states. And this lumber — most of it hardwood — is put to a variety of uses that require a wide range of qualities.

In recent years some studies have been made of lumber-marketing in attempts to aid the lumber producers.[1] These studies have described the lumber-marketing system in West Virginia and the Northeast from the viewpoint of the lumber manufacturer, and have defined the alternative methods of lumber production and marketing that are open to the producer in West Virginia.

To supplement these studies, the Forest Products Marketing Laboratory of the Northeastern Forest Experiment Station has turned its attention to the buyer, to determine his needs so that the West Virginia lumber producer can improve his marketing position by producing lumber that is designed to fit the needs of the buyer.

This study was designed to describe the lumber-purchasing activities of lumber users in selected areas of Virginia, North Carolina, and Ohio — states that contain important lumber markets for West Virginia lumber but were not included in the previous studies.

The area selected for study was delineated to include the Virginia cities relatively close to the West Virginia boundary such as Winchester, Roanoke, Pulaski, Bluefield, and Marion;

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[1] Christensen, Wallace W., Henry H. Webster, Gregory Baker, and others. MARKETING OF LUMBER PRODUCED BY SAWMILLS IN THE NORTHEAST — PHASE I. W. Va. Agr. Expt. Sta. Bull. 478, 32 pp., illus., 1962.

Whitmore, Roy A., Perry R. Hagenstein, William H. Reid, and Donald E. Nelson. MARKETING OF LUMBER IN THE NORTHEAST, PHASE II — LUMBER PURCHASES BY WOOD PRODUCTS MANUFACTURERS. Vt. Agr. Expt. Sta. Bull. 635, 38 pp., illus., 1963.

the North Carolina furniture centers such as High Point, Hickory, Thomasville, and Drexel; and Cincinnati, Columbus, and Cleveland and the cities in eastern Ohio (fig. 1).

Six lumber-using industries that provide the major lumber market outlets were selected for study: dimension and flooring, millwork, prefabricated structures, wooden containers, furniture and fixtures, and pallets.[2] Individual firms in each industry were selected for sampling, and managers were interviewed[3] about their lumber-purchasing activities for the year 1960. The data obtained for each industry were then expanded, based on sample percentages, to represent the whole of the industry in the study area.

This report describes the lumber-purchasing activities of these industries in the selected portions of the three-state area. It is directed primarily to the questions: (1) What type of lumber do they buy? and (2) How do they buy it? Although primarily of a descriptive nature, the report also identifies structural deficiencies in the marketing chain for lumber that need improvement or further research. This information is necessary to evaluate corrective actions by the lumber seller and/or buyer. And such information should help the lumber manufacturer to recognize the needs of the lumber user and to produce a product designed to fit these needs.

The Lumber

The value and specifications of the products manufactured by the six industries covered in the study differ considerably.

The products of the dimension-and-flooring, millwork, and furniture-and-fixtures industries are generally high-value products, reflecting the large amount of labor required in their production and the considerable change in form that the lumber undergoes during manufacture. Factors such as correct size and moisture content of the wood are critical in the final products of this group of industries.

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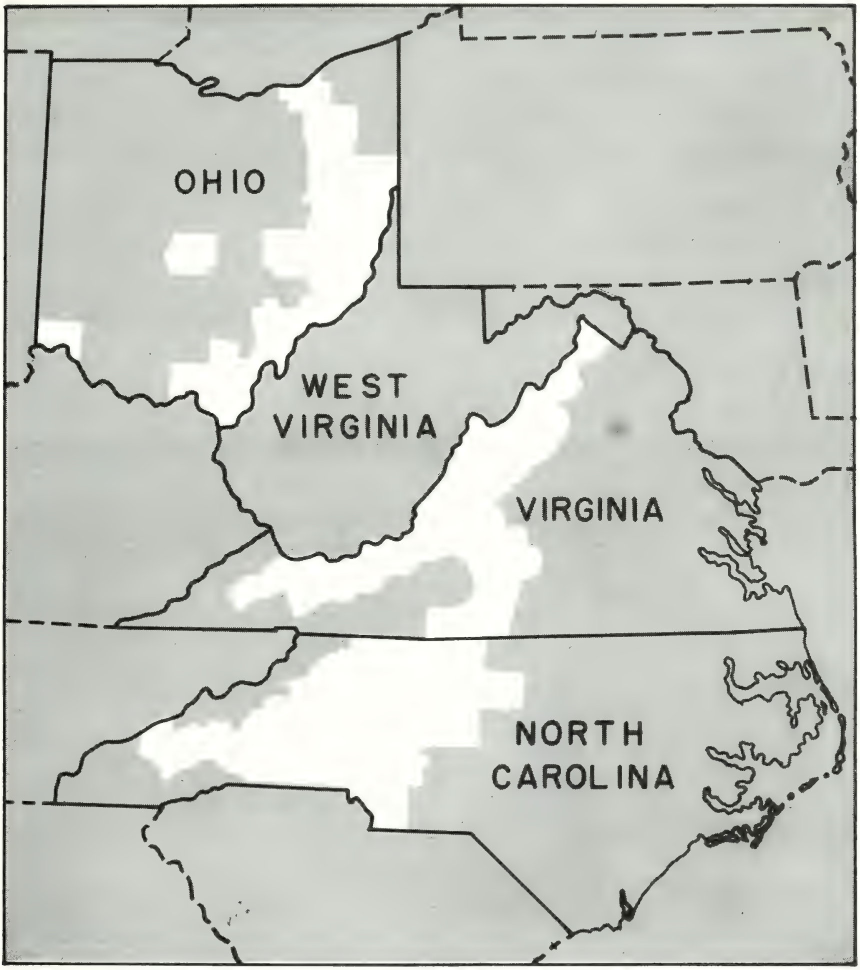
[2] The firms contacted in this group are classified under *Wood products, not elsewhere classified* in the Standard Industrial Classification. However, since nearly all of these firms interviewed in this study produced pallets as their major product, for convenience the industry will be referred to in the remainder of this report as the pallet industry.

[3] The interviews were conducted by William H. Reid, formerly with the West Virginia Agricultural Experiment Station, now with the Forest Products Requirements Branch, Division of Forest Economics Research, Forest Service, U. S. Department of Agriculture.

Figure 1.—The study area. Unshaded zones delineate areas of important markets for West Virginia lumber.



The manufacturers of wooden containers and pallets deal with low-value products, which are manufactured with a minimum number of operations. Correct size and moisture content of wood are important, but are not so critical in these products as in those mentioned above.

The prefabricated-house components manufactured by the prefabricated-structures industry are high-value products, yet are manufactured under capital-intensive processes. The manufacture of house components utilizes primarily the structural grades of softwood lumber in the standard sizes and condition, and this raw material undergoes relatively little change during the manufacturing process.

The variation of capital inputs among these three groups is reflected in the volumes of lumber processed annually per employee. The dimension-and-flooring, millwork, and furniture-and-fixtures industries were found to process 25,000 board feet of lumber per employee annually, while the wooden-container and the pallet industries utilized 42,000 board feet of lumber per employee annually. The prefabricated-structure industry was the most labor extensive-capital intensive industry: it processed 53,000 board feet of lumber annually per employee.

All together these six industry groups in the study area utilized approximately 1.6 billion board feet of lumber in 1960. Of this, 1.5 billion board feet (89 percent) was purchased from lumber manufacturers or lumber distributors. The remaining 171 million board feet (11 percent) was obtained from company-owned or contract sawmills.

Of the 1.5 billion board feet of purchased lumber, 1.4 billion board feet was purchased for remanufacture into the finished product. The rest was purchased for shipping containers and blocking for use in transporting the product. The furniture industry was the only user of lumber for such shipping purposes, a

Table 1. — *Hardwood and softwood lumber purchased for production use by industry in study area, 1960*[1]

Industry	Hardwood lumber		Softwood lumber		Total hardwood & softwood	
	Million bd. ft.	*Percent*	*Million bd. ft.*	*Percent*	*Million bd. ft.*	*Percent*
Dimension and flooring	117	10	3	1	120	9
Millwork	100	9	150	65	250	18
Prefabricated structures	10	11	54	23	64	5
Wooden container	52	4	5	2	57	4
Furniture and fixtures	875	76	18	8	894	64
Pallet	2	([2])	2	1	4	([2])
Total	1156	100	232	100	1390	100

[1] Data may not add to totals because of rounding.

[2] Less than 0.5 percent.

Table 2. — *Percentage of lumber purchased, by State and industry in study area*

Industry	Ohio	North Carolina	Virginia
	Percent	*Percent*	*Percent*
Dimension and flooring	7	38	55
Millwork	11	8	81
Prefabricated structures	12	0	88
Wooden container	65	(1)	35
Furniture and fixtures	2	61	37
Pallet	13	87	0
All industries	7	45	48

[1] Less than 0.5 percent.

reflection of the relatively high value and form of the finished product.

The furniture-and-fixtures industry represented the most important market outlet for lumber: it accounted for nearly two-thirds of the total volume of hardwood and softwood lumber purchased for production use (table 1).

However, the furniture industry is not as important in the wood-products-manufacturing complex as the figures seem to indicate. For example, in West Virginia, furniture and fixtures accounted for only 10 percent of the lumber manufactured into wood products.[4] Nationally, about 21 percent of the lumber used in manufactured products in 1960 was processed into furniture.[5]

The millwork industry was the most important market outlet for softwood lumber in the study area. It accounted for nearly two-thirds of the softwood lumber purchases. However, less than 20 percent of the lumber purchased for production use in the study area was of the softwood species.

The dimension-and-flooring, millwork, and prefabricated-structures industries are concentrated primarily in Virginia (table 2). North Carolina is the main area of market concentration for the furniture-and-fixtures industries and the pallet industry, and Ohio for the wooden-container industry.

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[4] Reid, W. H., W. W. Christensen, and N. D. Jackson. MARKETING OF LUMBER PRODUCED BY SAWMILLS IN WEST VIRGINIA. W. Va. Agr. Expt. Sta. Interim Rpt., 20 pp., illus., (n.d.).

[5] Gill, Thomas G. WOOD USED IN MANUFACTURING INDUSTRIES. U. S. Forest Serv. Statis. Bul. 353, 121 pp., illus., 1965.

Although the data were collected and tabulated on the basis of firm size (number of employees), there was no apparent correlation between size of firm and procurement activities. The firm size classes were as follows:

I	1 - 50 employees
II	51 - 100 employees
III	Over 100 employees

With increasing firm size, there was an increase in the number of suppliers from whom they purchased lumber.

Purchasing Activities

The following sections are concerned with the 1.4 billion board feet of lumber purchased for remanufacture into finished product, specifically in relation to: (1) the physical characteristics of the lumber purchased by each industry; (2) the source of the lumber; (3) the conditions under which each industry purchased its lumber; (4) the difficulties the various industries have experienced in purchasing lumber; and (5) solutions found helpful in overcoming these difficulties.

Lumber Requirements

Species. — The lumber used by manufacturers was classified only as hardwood or softwood species. Major differences were found between industries in the relative amounts of hardwood and softwood lumber they utilized for different products.

The dimension-and-flooring, wooden-container, and furniture-and-fixtures industries are predominately users of hardwood lumber. The prefabricated-structures and millwork industries utilize mainly the softwood species. The pallet industry utilizes comparable volumes of both hardwood and softwood species. In the study area, over four-fifths of the lumber purchased was hardwood, the remaining one-fifth softwood (table 3).

Grade. — Lumber purchased on a standard-grade basis was classified in the study only as high quality or low quality — class 1 or class 2. High-quality lumber was considered to be No. 1 common and better for hardwood lumber and No. 2 common and better, sterling, or standard for softwood lumber. The low-quality lumber was designated as No. 2 common and poorer for hardwood lumber and No. 3 common and poorer, construction, or utility grades for softwood lumber.

Table 3. — *Percentage of hardwood and softwood lumber purchased, by industry in study area*

Industry	Hardwood lumber	Softwood lumber
Dimension and flooring	97	3
Millwork	40	60
Prefabricated structures	16	84
Wooden container	91	9
Furniture and fixtures	98	2
Pallet	51	49
All industries	83	17

Several firms in the prefabricated-structures and furniture-and-fixtures industries indicated that they purchased portions of their softwood lumber requirements on a private grade basis. These grades evidently reflected the needs of the user and cannot be specified as representing either the higher or lower grades of lumber to any marked degree.

The grades of hardwood and softwood lumber utilized predominately by the various industries are presented in the following tabulation:

Industry	*Hardwood lumber (grade)*	*Softwood lumber (grade)*
Dimension and flooring	Low	High
Millwork	High	High
Prefabricated structures	Low	(*)
Wooden container	Low	Low
Furniture and fixtures	High-low	(*)
Pallet	Low	Low

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* Undefinable from the data.

Data for the dimension-and-flooring industry are somewhat confounded by the way in which these two large lumber users are grouped together in the Standard Industrial Classification. The production of dimension stock and the production of flooring require different grades and species of lumber. In our study, the low-grade hardwood lumber was purchased primarily by the flooring industry while the high-grade softwood lumber was used primarily by the dimension industry.

Overall, four-fifths of the hardwood lumber used by plants in the study area was purchased on a standard grade basis.

Table 4. — *Percentage of hardwood and softwood lumber purchased on a standard grade, private grade, or ungraded basis, by industry in study area*

Industry and species	Standard grades		Private grades	Ungraded
	Class 1	Class 2		
Dimension and floooring:				
Hardwood	33	67	0	0
Softwood	65	16	0	19
Millwork:				
Hardwood	62	19	0	19
Softwood	90	10	0	0
Prefabricated structures:				
Hardwood	0	100	0	0
Softwood	11	31	58	0
Wooden container:				
Hardwood	43	54	0	3
Softwood	23	70	0	7
Furniture and fixtures:				
Hardwood	35	41	0	24
Softwood	37	0	63	(1)
Pallet:				
Hardwood	0	66	0	34
Softwood	0	100	0	0
All industries:				
Hardwood	38	42	0	20
Softwood	65	16	18	1

[1] Less than 0.5 percent.

Approximately two-fifths was in the class 1 category and two-fifths was class 2. The remaining one-fifth was purchased ungraded (table 4).

Softwood lumber was purchased in a variety of grades. Some 65 percent was class 1 and 16 percent was class 2. The remaining 18 percent was purchased under private grades. Less than 1 percent was purchased as ungraded lumber.

Condition. — The condition of lumber at the time of purchase was classified as (1) green or dry and (2) rough or finished. The condition of the bulk of the hardwood and softwood lumber purchased by each industry was determined to be as follows:

Industry	*Hardwood*	*Softwood*
Dimension and flooring	Green-rough	Dry-finished
Millwork	Dry-rough	Dry-rough
Prefabricated structures	Green-rough	Green-rough
Wooden container	Green-rough	Green-rough
Furniture and fixtures	Dry-rough	Green-rough
Pallet	Green-finished	Dry-finished

Overall, two-thirds of the hardwood and four-fifths of the softwood lumber was purchased in a dry condition (either air-dried or kiln-dried). Approximately nine-tenths of the hardwood and four-fifths of the softwood lumber was purchased rough (table 5).

Table 5. — *Condition of hardwood and softwood lumber purchased by industry in study area*

Industry and species	Condition			
	Green	Dry[1]	Rough	Finished
	Percent	*Percent*	*Percent*	*Percent*
Dimension and flooring:				
Hardwood	76	24	100	0
Softwood	23	77	35	65
Millwork:				
Hardwood	38	62	100	(2)
Softwood	0	100	90	10
Prefabricated structures:				
Hardwood	100	0	100	0
Softwood	53	47	53	47
Wooden container:				
Hardwood	53	47	52	48
Softwood	79	21	72	28
Furniture and fixtures:				
Hardwood	24	76	93	7
Softwood	63	37	63	37
Pallet:				
Hardwood	100	0	35	65
Softwood	11	89	0	100
All industries:				
Hardwood	32	68	93	7
Softwood	20	80	78	22

[1] Less than 25 percent moisture content.

[2] Less than 0.5 percent.

The condition of the lumber when purchased by each industry is mainly a reflection of the product requirements. Since hardwood lumber is commonly remanufactured and is significantly changed in form in the final product, the bulk of the hardwood lumber was purchased in a rough condition.

Lumber in a rough condition is suitable for the manufacture of shipping containers, consequently the wooden-container industry also purchased the bulk of its lumber in a rough condition. Pallets generally require smooth surfaces; so surfaced lumber was usually purchased for their manufacture.

Since one-third of the hardwood lumber was purchased green and much of the dry lumber was merely air-dried, it is apparent that the secondary industries have absorbed much of the drying function. Green lumber is acceptable only for portions of the products of the wooden-container and the pallet industries. The large amount of lumber purchased green or in a dry condition, especially by the furniture industry, was usually dried more thoroughly in kilns at the plant. This permitted the plant to exert closer control over drying and over the quality and condition of the lumber used in their manufacturing operations.

Sources of Lumber

The lumber source was investigated to determine both the geographical source and market source of the purchased lumber. The geographical source refers to the state or region in which the lumber was manufactured. The market source was further classified as a lumber manufacturer or intermediate market agent (commission men, brokers and wholesalers), depending on whether the lumber was shipped directly from the sawmill to the consumer or through a distributor.

Except in Ohio, the industries studied generally purchased their lumber from in-state sources. Industries in Ohio purchased the bulk of their hardwood lumber from Ohio sources, but nearly all of their softwood lumber came from out-of-state sources, mainly from the West Coast.

Although West Virginia ranked fourth in volume as a supplier of lumber, it contributed less than 10 percent of the lumber purchased by firms in the study area (table 6). It is worth noting that more than half of the lumber used by plants covered in the study area originated in Virginia and North Carolina, and that these two states and the other Southeastern States produced two-thirds of the lumber used in the study area.

The study showed that three-fifths of the hardwood and soft-

Table 6. — *Geographical source of hardwood and softwood lumber for the study area*

Geographical source	Hardwood lumber		Softwood lumber		All lumber	
	Million bd. ft.	*Percent*	*Million bd. ft.*	*Percent*	*Million bd. ft.*	*Percent*
Virginia	361,199	31.3	80,698	34.7	441,897	31.8
North Carolina	285,945	24.7	53,700	23.1	339,645	24.5
Southeastern States	108,800	9.4	4,822	2.1	113,622	8.2
West Virginia	102,530	8.9	84	([1])	102,614	7.4
Gulf States	84,938	7.3	315	.1	85,253	6.1
West Coast	0	—	82,906	35.7	82,906	6.0
Lake States	53,460	4.6	0	—	53,460	3.8
Ohio	42,261	3.7	2,910	1.3	45,171	3.3
Pennsylvania	43,589	3.8	0	—	43,589	3.1
Foreign	18,906	1.6	250	.1	19,156	1.4
Maryland	14,658	1.3	0	—	14,658	1.1
Kentucky	13,683	1.2	14	([1])	13,697	1.0
New York	12,660	1.1	0	—	12,660	.9
Arkansas	4,176	.4	6,094	2.6	10,270	.7
Tennessee	3,677	.3	565	.2	4,242	.3
Missouri	3,828	.3	0	—	3,828	.3
Other	1,546	.1	112	.1	1,658	.1
Total	1,155,856	100.0	232,470	100.0	1,388,326	100.0

[1] Less than 0.05 percent.

Table 7. — *Percent of hardwood and softwood lumber obtained from lumber manufacturers and/or market intermediaries by industry in study area*

Industry	Hardwood		Softwood	
	Lumber manufacturers	Market intermediaries	Lumber manufacturers	Market intermediaries
Dimension and flooring	90	10	35	65
Millwork	76	24	56	44
Prefabricated structures	100	0	63	37
Wooden container	99	1	89	11
Furniture and fixtures	50	50	98	2
Pallet	99	1	100	0
All industries	59	41	62	38

wood lumber used by the industries sampled was purchased directly from lumber manufacturers and two-fifths from intermediaries such as brokers and wholesalers (table 7). One might expect that the industries that utilize primarily the higher grades of lumber would purchase a greater amount of lumber from intermediate market agents. This tendency was not evident from the data.

Conditions of Purchase

As an indication of the efficiency of the existing marketing system for lumber, each firm was asked to specify the transaction conditions, such as delivery method, ordering method, pricing point, method of payment, and the existence of business ties between the firms and their suppliers.

Transaction conditions. — The results showed that lumber was transported from the supplier to the lumber-using firms mainly by truck. Three-fourths of the hardwood lumber and three-fifths of the softwood lumber was delivered by truck (table 8).

The mode of transportation was affected by the geographical source of the lumber. For example, the millwork and the wooden-container industries purchased the bulk of their hardwood lumber from out-of-state sources. Consequently, as a matter of economics, they were the primary recipients of rail-delivered hardwood lumber. And proportionately, more softwood lumber was purchased from out-of-state sources than hardwood lumber. Accordingly, a larger proportion of the softwood lumber was also rail-delivered since rail transportation is more economical for

Table 8. — *Percentage of hardwood and softwood lumber delivered by rail or truck, to industry in study area*

Industry	Hardwood		Softwood	
	Rail	Truck	Rail	Truck
Dimension and flooring	6	94	72	28
Millwork	56	44	50	50
Prefabricated structures	0	100	24	76
Wooden container	48	52	25	75
Furniture and fixtures	22	78	36	64
Pallet	0	100	78	22
All industries	24	76	43	57

Table 9. — *Ordering method for hardwood and softwood lumber, by industry in study area*

Industry	Hardwood: Order sent to supplier	Hardwood: Supplier calls	Hardwood: Other	Softwood: Order sent to supplier	Softwood: Supplier calls	Softwood: Other
Dimension and flooring	45	35	20	72	28	0
Millwork	67	18	15	98	2	0
Prefabricated structures	20	80	0	44	56	0
Wooden container	21	14	65	76	5	19
Furniture and fixtures	68	32	0	100	0	0
Pallet	22	78	0	78	22	0
All industries	63	30	7	85	15	(1)

[1] Less than 0.5 percent.

the longer haul. Undoubtedly firm preferences due to such factors as a lack of rail facilities adjacent to user's yards have had an effect on the mode of transportation, but our study was not designed to record and evaluate differences of this sort.

Simply phoning or sending an order to the lumber supplier was found to be the general ordering method by all industries covered in the study. More than three-fifths of the hardwood lumber and more than four-fifths of the softwood lumber was ordered in this fashion (table 9). But the ordering method was affected to a minor degree by the geographical source of the lumber; the close proximity of lumber suppliers to a number of the industries facilitated an occasional sales call in person by the lumber supplier. Sending the order to the supplier was more common for industries that had a variety of lumber sources.

More than 95 percent of all the lumber purchased was purchased at prices based on delivery to the buyer's plant. Evidently all of the industries were concerned only with the cost of lumber at their yard and preferred to leave the responsibility for transportation to the supplier.

Most of the lumber was purchased on a cash sale basis. This system commonly allows a 2-percent discount if payment is made within 10 days or payment in cash net within 30 to 60 days after receipt of the lumber. Less than 1 percent of the lumber was purchased on credit advanced by the seller, and none of the lumber was purchased on an advance-payment basis.

Relationships with lumber suppliers. — The number of lumber suppliers selling lumber to each firm varied in relation to the size of firms (number of employees) and between firms in different industries. This was a reflection of the greater volume of lumber required by larger firms and the greater variety of types of lumber required by certain industries. The average number of suppliers per firm ranged from 10 in the millwork industry to 37 in the prefabricated-structures industry; this corresponded with the increasing average size of firm. The millwork industry commonly requires fewer types of lumber to meet the needs of a relatively narrow market. The prefabricated-structures industry, on the other hand, commonly requires a greater variety of types of lumber as found in residential construction. An average of 22 lumber suppliers served each firm.

Lumber users had dealt with each of their lumber suppliers for an average of 6 years in the pallet industry to 9 years in the wooden-container industry. The average length of time for all firms covered in the study was 7 years. One-half of the firms indicated that it was primarily the seller's initiative through sales calls and/or correspondence that brought their firm and a potential lumber supplier together. Approximately one-fourth of the lumber-buying firms reported that they were forced to take the initiative in locating a potential lumber supplier; the other one-fourth of the firms felt that it was a mutual buyer-seller effort.

Only 1 percent of the firms, primarily in the millwork and the wooden-container industries, indicated that they negotiated for contractual arrangements between their firm and a lumber supplier. These contracts ranged from 6 months to 3 years in duration. Only one of these firms indicated that they paid a premium price to their contractor. All other firms indicated that these contracts were on a market-price basis.

A number of lumber-using firms in each industry indicated that they were engaged in other business dealings with their lumber suppliers. Most commonly these dealings included the purchase of other materials or services. Fourteen percent of the total number of firms indicated dealings of this sort with their lumber supplier. A few firms, particularly in the pallet industry, indicated that they were jointly engaged in other businesses with their lumber supplier or suppliers. Fewer than 1 percent of the firms indicated having business dealings of this sort with their lumber suppliers.

Lumber-Purchasing Difficulties

Lumber-purchasing firms were asked a number of questions about lumber-procurement problems. They were also asked to segregate their present procurement problems from past (since 1955) procurement problems. And they were asked to indicate any geographical aspects of their lumber-purchasing difficulties.

Twenty-eight percent of the firms indicated that they were currently having lumber-procurement difficulties (table 10). And 34 percent of the firms indicated that they have had lumber-procurement difficulties in the past. Because of the different lengths of time taken for a base for present and past difficulties, however, this does not mean there has been a reduction in lumber-procurement difficulties, or any change at all.

The occurrence of current lumber-procurement problems was most evident in the furniture- and fixtures-industry: more than one-third of the firms mentioned such difficulties. This was a marked increase over the number of firms that expressed procurement difficulties in the past.

Firms that indicated having present or past lumber-procurement problems were asked to specify the nature of these problems and to rank these problems as constituting a major or relatively minor difficulty. Their responses were as follows:

PRESENT DIFFICULTIES

Industry	*Major difficulty*	*Minor difficulty*
Dimension and flooring	Correct size	Correct size
Millwork	Proper seasoning	Delivery assurance
Prefab structures	None	None
Wooden container	Delivery assurance	Correct size
Furniture and fixtures	Proper grade	Correct size
Pallet	None	None

PAST DIFFICULTIES

Industry	*Major difficulty*	*Minor difficulty*
Dimension and flooring	Correct size	Proper species
Millwork	Proper seasoning	Delivery speed
Prefab structures	None	Proper seasoning
Wooden container	Delivery assurance	Correct size
Furniture and fixtures	Proper grade	Correct size
Pallet	Delivery assurance	Delivery assurance

The prefabricated-structures industry and the pallet industry indicated that they were not experiencing any current lumber-procurement difficulties. Both of these industries utilize primarily

Table 10. — *Number and percent of firms expressing present or past procurement problems, by industry in study area*

Industry	Present difficulties		Past difficulties	
	No.	*Percent*	*No.*	*Percent*
Dimension and flooring	7	21	20	59
Millwork	10	6	71	45
Prefabricated structures	0	—	5	56
Wooden container	6	22	6	22
Furniture and fixtures	155	39	110	27
Pallet	0	—	2	50
All industries	178	28	214	34

the lower grades of lumber, indicating that problems dealing with the proper grades of lumber are of primary importance. This was generally the case, as 44 percent of the firms reporting current lumber-procurement difficulties of major importance indicated that non-conformance to lumber grade specifications was their most important problem (table 11). More than one-half of the firms that expressed present difficulties also indicated that they were having difficulty obtaining properly sized lumber, but this was generally felt to be a relatively minor problem.

Table 11. — *Present major and minor lumber-procurement difficulties for all industries in study area*

Form of difficulty	Major difficulty		Minor difficulty	
	No. of firms	*Percent*	*No. of firms*	*Percent*
1. Speed of delivery	0	0	7	4
2. Assurance of delivery	14	10	20	12
3. Conformance to specifications	131	90	124	74
Grade	64	44	6	4
Size (accuracy of manufacture)	2	1	92	55
Species	2	1	15	9
Condition (seasoning)	3	2	5	3
4. Other	1[1]	([2])	16[3]	10
Total	146	100	167	100

[1] Shortage of lumber.

[2] Less than 1 percent.

[3] Need for mixed grades in carload shipments; excessive price; lengths too short.

The major problem most often indicated as a past difficulty was also nonconformance to specifications of the lumber, particularly grade specifications (table 12). Of those past problems indicated as relatively minor, size or accuracy of manufacture of the lumber was most often mentioned.

Table 12. — ***Past major and minor lumber-procurement difficulties for all industries in study area***

Form of difficulty	Major difficulty		Minor difficulty	
	No. of firms	*Percent*	*No. of firms*	*Percent*
1. Speed of delivery	0	0	64	25
2. Assurance of delivery	17	15	18	7
3. Conformance to specifications	97	83	151	59
Grade	25	21	7	3
Size (accuracy of manufacture)	2	2	93	36
Species	2	2	16	6
Condition (seasoning)	15	13	19	7
Quantity	0	—	1	1
4. Other	3[1]	2	23[2]	9
Total	117	100	256	100

[1] Species shortage.

[2] Species shortage; need for mixed grades in carload shipments.

The problem of mismanufactured and improperly processed lumber assumes much more extensive proportions. This accounted for 90 percent of the current major difficulties. The minor difficulties most often indicated were also concerned with conformance to specifications.

Only 10 percent of the firms indicated that they were experiencing difficulties between geographic areas in terms of purchasing difficulties. The greatest difficulty expressed was with lumber shipments from Pennsylvania and New York. Cause of this is not known.

The majority of the firms that indicated that they were having less trouble with shipments from a particular area reported that West Virginia lumber shipments gave them the least difficulty. Pennsylvania was also mentioned in this regard, however, indicating that the degree of satisfaction obtained varies within a state or region and, most likely, among individual lumber suppliers.

Solutions for Overcoming Difficulties

Lumber-buying firms were queried as to the actions they had found most helpful in overcoming lumber-purchasing difficulties and to indicate what they considered was a major action and which was a relatively minor action. Each firm was also asked to specify what major factors as well as any other relatively minor factors they considered in choosing a lumber supplier.

More than three-fourths of the firms taking major actions reported that they switched to other suppliers (table 13). Most of the remaining firms turned to intermediate market agents, and only 1 percent of the firms offered a premium price for prompt delivery and well-manufactured and well-seasoned lumber.

Switching suppliers was also most often indicated as a relatively minor action taken by the lumber-buying firms. Approximately one-fourth of the firms indicated that they paid a premium price for properly manufactured and processed lumber and good service, but that they generally considered this to be a relatively minor action.

Conformance to specifications of the lumber was most often indicated by the firms as the major factor influencing their choice

Table 13. — *Actions taken by industries in study area to overcome lumber-procurement difficulties*

Action	Major action		Minor action	
	No. of firms	*Percent*	*No. of firms*	*Percent*
Used market intermediaries	18	12	0	—
Rejected lumber that did not conform with specifications	12	8	10	5
Paid premium price	2	1	56	27
Switched suppliers	120	78	58	28
Switched supply area	0	—	28	13
Switched to dimension stock	0	—	48	23
Other	2[1]	1	8[2]	4
Total	154	100	208	100

[1] Attempt to acquaint supplier with lumber needs.

[2] Increase inventory, switch species.

Table 14. — *Factors influencing choice of lumber suppliers for all industries in study area*

Factor	Major factor		Minor factor	
	No. of firms	*Percent*	*No. of firms*	*Percent*
Only supplier available	0	—	1	(1)
Price	5	1	81	15
Delivery speed	92	16	2	(1)
Delivery assurance	154	27	253	48
Size of purchases	0	—	24	5
Conformance to specifications	267	46	159	30
Reputation of supplier	41	7	3	1
Species requirements	8	1	4	1
Other	11[2]	2	2[3]	(1)
Total	578	100	529	100

[1] Less than 0.5 percent.

[2] Social ties between buyer and seller.

[3] Local supplier; odd sizes.

of a lumber supplier, indicating the importance of properly manufactured and processed lumber. Nearly one-half of the firms considered this as a major factor (table 14). Delivery assurance and delivery speed were considered major determining factors by another 43 percent of the firms. Only 1 percent of the firms felt that price was the major factor influencing their choice of a lumber supplier.

Of the relatively minor factors, assurance of prompt delivery was most often mentioned. More than three-fourths of the firms considered delivery assurance and conformance to specifications as factors in choosing a lumber supplier.

Discussion

Our study of the leading industrial markets for lumber from the southern Appalachian region, and in particular, lumber from West Virginia, suggests some areas that need further research.

One factor emphasized is the large extent to which the marketing functions and even the lumber-processing functions have been absorbed by the lumber user. At present approximately three-fifths of the lumber moves directly from the lumber manufacturer to the lumber user. Contractual arrangements or financial ties between the lumber supplier and user were notably lacking, resulting generally in a buyer's market.

Research is needed to determine what effect the intermediate agent has on the lumber-distribution system at present, and how much more or less of an active role he should be encouraged to play. Perhaps the intermediate market agent rather than the lumber manufacturer or lumber user is in a better market position to offer the marketing functions of information, exchange, physical supply, and financial service. In addition, the intermediate stage between producer and user may be a more favorable time for some of the lumber-processing functions that are now often passed on to the lumber user, such as drying. Analyses of the present and prospective roles of the intermediate market agent ought to be made in terms of marketing efficiency.

Another point evident from the data is the continuing problem of mismanufactured lumber. Manufacturing firms apparently have no difficulty in procuring the quantity of lumber needed, but they do experience difficulties with the quality of lumber that is available on the market. When many suppliers are available, lumber users are not forced to offer a premium price for quality lumber, but usually try to solve their problems by switching to other suppliers. Thus the average firm's main concern in choosing a lumber supplier is not price or delivery speed but the supplier's adherence to quality specifications.

Much of the value of hardwood lumber is determined in the logging and sawing processes. Mistakes made at this stage usually cannot be easily or economically remedied later. Thus research and extension efforts directed at the woods and the mill, to produce a more satisfactory product, might improve the later marketing situation.

An analysis of the prospective costs and returns of a program of quality control for the individual sawmill might also be helpful. Such a program, of course, implies added costs to the lumber manufacturer. And there is no evidence that the lumber user will recognize these added costs in terms of higher prices or an expanded demand for the lumber. Yet mismanufactured lumber seems to be contributing to the conversion to substitute materials and the resulting dwindling lumber markets. Results of our study suggest that research in this area should have top priority, at least from the lumber purchaser's point of view. The result could be a more satisfactory product for the lumber user and an expanded demand for lumber.

■

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Germination of Eastern White Pine Seed

as influenced by stratification

by Raymond E. Graber

The Author

RAYMOND E. GRABER received his Bachelor of Science degree in forestry from the University of Washington in 1957. He then worked for 2 years in farm forestry and state forest management before taking graduate studies in forest ecology at Oregon State University. His service with the Northeastern Forest Experiment Station, which he joined as a research forester in July 1961, has been devoted largely to problems of regeneration of white pine. At present he is associate plant ecologist on the staff of the Massabesic Experimental Forest at Alfred, Maine.

Germination of Eastern White Pine Seed

as influenced by stratification

STRATIFICATION has been a standard practice for many years in conditioning tree seed for testing or for sowing in forest nurseries. Literally, the term means to place the seed in layers, and originally the treatment involved placing layers of seed between layers of a moisture-retaining medium such as peat moss or sand. However, the layering is incidental; the essential conditions are moistness and low temperature, and the term stratification is now applied to any seed treatment that provides those conditions. It is so used in this paper.

Stratification breaks dormancy, insuring rapid and uniform germination as soon as conditions become favorable. In nature this process occurs as seeds over-winter on the forest floor. But when dormant seeds, such as those of white pine *(Pinus strobus)*, are sown in the spring, stratification is necessary to prepare the seeds for germination. This treatment is particularly necessary for direct seeding, where fast and complete germination may be the deciding factor between adequate stocking or failure.

Direct seeding can be done either in the fall, with untreated seed, or in the spring, with stratified seed. Spring seeding has an advantage: the seed is exposed to predators for the minimum time.

Even though the practice of stratifying white pine seed is widely used and recommended,[1] no detailed statistical evaluation of the effects of stratification on this species has been published. The purpose of this study was to measure the influence of stratification temperature and length of stratification period on the completeness and speed of germination in white pine seed.

MATERIALS AND METHODS

Three white pine seed collections were made in 1961 within a 30-mile radius in southwestern Maine. The cones were air-dried and seed was extracted in a small tumbler. The seeds were dewinged by hand and winnowed to remove inert matter and empty seeds. They were then dried to a moisture content of 5 percent and stored at 36°F. for 14 months.

Seeds, in lots of 50, were placed in petri dishes on water-saturated kimpack (a highly absorbent sterile germination paper) and stratified in refrigerators at three constant temperatures: 36 ± 1°F., 40 ± 1°F., and 50 ± 2°F. Each refrigerator was illuminated continuously with a 15-watt incandescent light.

After stratification the seeds were rinsed in tap water and replaced in the petri dishes on clean saturated kimpack. The seeds were incubated 40 days at 68-86°F. (alternating 86°F. for 8 hours with natural light and 68°F. for 16 hours in darkness). Germination counts were made daily for the first 20 days and at 2-day intervals thereafter. A seed was counted when the emerging radical was 2 mm. long or longer.

---

[1] Barton, L. V.: HASTENING THE GERMINATION OF SOME CONIFEROUS SEEDS; Amer. Jour. Bot. 17: 83-105, 1930.—Baldwin, H. I.: EFFECT OF AFTER-RIPENING TREATMENT OR GERMINATION OF WHITE PINE SEEDS OF DIFFERENT AGES; Bot. Gaz. 96: 372-376, 1934.—United States Forest Service: WOODY-PLANT SEED MANUAL; U. S. Dept. Agr. Misc. Pub. 654, 416 pp., illus., 1948.

After 40 days of incubation the ungerminated seeds were cut longitudinally and inspected. All well-filled seeds with fully developed embryos were considered viable. Germination percentage was based on the total number of viable seeds. The number of days required to attain 33 1/3 percent germination of the viable seeds was used as a measure of the rate or speed of germination. This benchmark, 33 1/3 percent was selected because in nearly all cases germination reached or exceeded that amount in the 40-day period, thus allowing statistical comparisons of the treatments to be made.

The study was divided into two parts. In Experiment I, the treatment combinations of stratification period and temperature included the range of those commonly recommended for eastern white pine seed. Seed from the three collection sources was stratified at 36°, 40°, and 50°F. for 10, 30, 60, and 90 days. These treatments were replicated three times with 50 seeds per replicate. A control (no stratification) was added for each seed source; however, the control data were not included in the analysis. Analysis of variance was used to evaluate the effects of the treatments and orthogonal comparisons were made to locate significant differences.

Experiment II was carried out to further elucidate the effects of stratification period. It was restricted to one seedlot—8-61-L—and to one temperature—40°. The additional stratification periods tested were 1, 5, 20, and 45 days. These treatments were replicated four times. Another 50-seed replicate of seedlot 8-61-L was added to each of the Experiment I periods of 10, 30, 60, and 90 days at 40°, thus providing four replicates of all eight stratification periods for this seedlot and temperature. Since all seeds in both experiments were treated and germinated concurrently, statistical comparison (analysis of variance) of the eight periods was valid.

RESULTS

Experiment I

The effects of seed source and period of stratification on both percentage of germination and rate of germination were significant. Stratification temperature significantly affected only the rate of germination (table 1). All statements of statistical significance in this paper refer to the 1-percent level of probability.

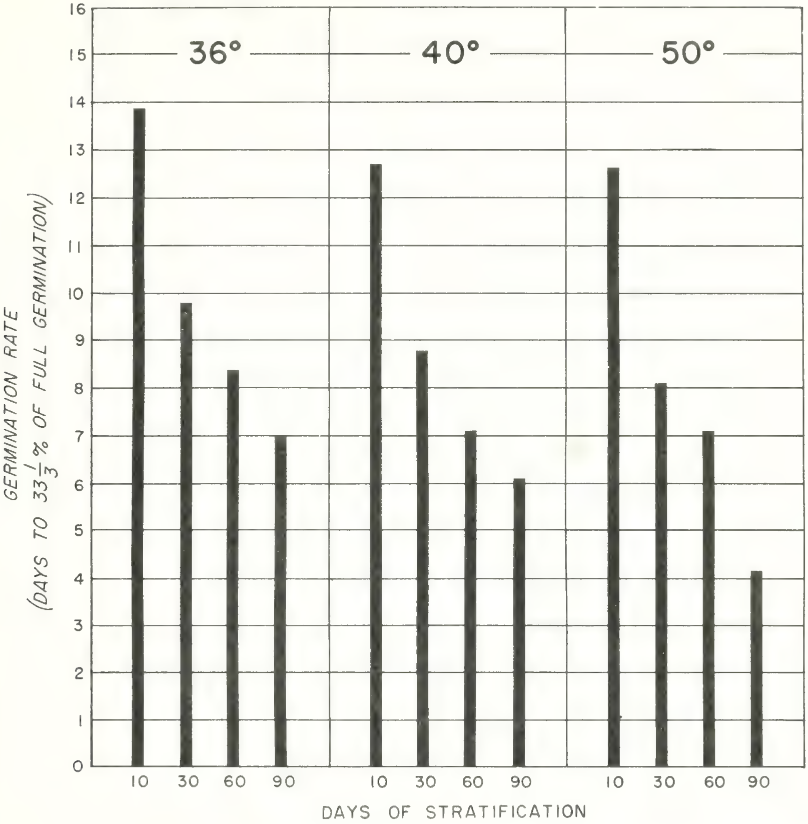
Seed source.—Although germination for seed source 6-61-A was significantly higher, the differences among the three sources were so small that they have little practical importance (table 1). The seed sources also differed in rate of germination: source 4-61-WC was significantly slower than source 6-61-A.

Stratification temperature. — Increasing stratification temperature above 36°F. resulted in a slightly greater (but not significant) percentage of germination (table 1).

Table 1.—Average percent germination and rate of germination as affected by seed source, stratification temperature, and stratification period

Item	Germination (percent)	Rate of germination (days to 33-1/3 percent of full germination)
Seed source:		
4-61-WC	89.9	9.33
6-61-A	94.8	8.25
8-61-L	91.8	8.72
Stratification temperature:		
36°F.	90.4	9.7
40°F.	93.1	8.2
50°F.	92.9	8.0
Stratification period (days):		
Control	43.2	—
10	70.0	13.0
30	98.9	8.7
60	99.7	7.6
90	99.9	5.7

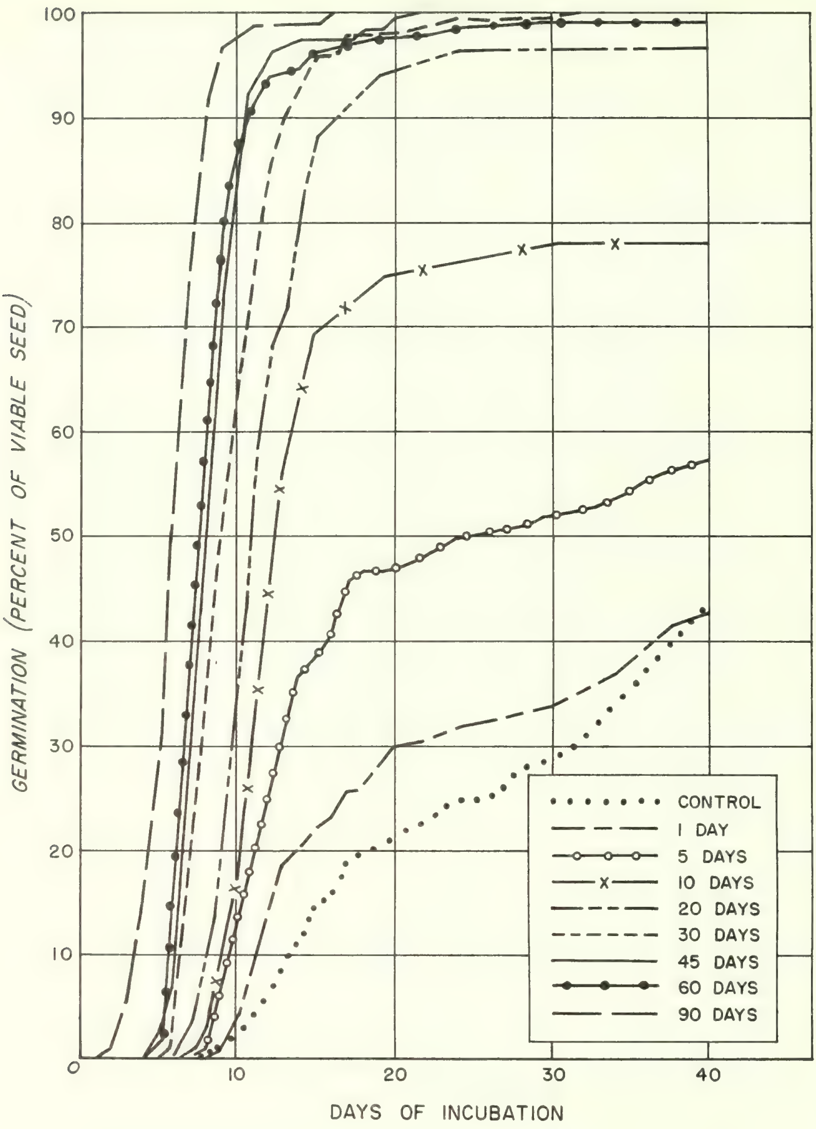
Figure 1.—Rate of germination as influenced by stratification temperature and period.



Speed of germination increased significantly with each increase in stratification temperature (fig. 1). Premature germination occurred at 50° when the stratification period was 60 days or longer. After 60 days' treatment, 1 percent of the seeds had germinated, and after 90 days an average of 32.4 per cent had germinated.

Stratification period.—Length of stratification period was the major factor affecting both amount and speed of germination. The 10-day period was insufficient to fully overcome seed dormancy, yet an average of 70 percent of the stratified seed germinated, compared to 43.2 percent of those in the untreated controls (table 1). Germination after 30 days of stratification was

Figure 2.—Patterns of germination during 40 days' incubation for white pine seed stratified for various periods at 40°F.



significantly lower than after the 60- and 90-day treatments, but the actual differences were only 1 percentage point or less, and thus of no practical importance. Under the test conditions, almost complete germination occurred after 30 or more days of treatment regardless of stratification temperature or seed source.

The effects of stratification period were more pronounced on the rate of germination than on the ultimate amount (fig. 1). Each increase in length of period significantly increased the rate of germination.

Experiment II

The additional stratification periods included in Experiment II resulted in highly significant differential responses in germination. Germination patterns for the eight stratification periods and the control are shown in figure 2. Nearly complete germination (96.5 per cent) occurred after only 20 days of stratification. The 5-day treatment, with 57 percent germination, was roughly intermediate between the control (43 percent) and the 10-day treatment (78 percent). One day of treatment had no effect: germination was identical with that for the control. An almost linear relationship was evident between length of stratification period and total germination for 1, 5, 10, and 20 days of treatment (fig. 3).

As expected, rate of germination increased with length of stratification period (table 2). The control and the 1-day treatment are omitted from this table because some replicates did not attain 33 1/3 percent germination during the 40-day incubation period.

Table 2.—Rate of germination of white pine seedlot 8-61-L for different periods of stratification at 40°F.

Period of stratification (days)	Rate of germination (days to 33 1/3 percent of full germination)
5	14.50
10	11.50
20	10.50
30	8.75
45	7.75
60	7.25
90	5.75

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STAND DIFFERENTIATION ABILITY in Northern Hardwoods

by Adrian M. Gilbert

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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STAND DIFFERENTIATION ABILITY

in Northern Hardwoods

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Importance of Stand Behavior

THERE ARE GAPS in our knowledge of forest stand behavior. In particular, we know little about differentiation in even-aged stands. We have observed for years that, within a stand, trees differentiate into diameter and crown classes. But few attempts have been made to measure this differentiation in even-aged stands, or to explain it.

There is an increasing interest in stand behavior. In New England, where this study was conducted, many public and private owners are placing their northern hardwood forests under management. Stumpage returns have reached levels high enough to induce some owners to practice siliculture on their managed lands.

The opportunities for research are increasing too. Each added piece of knowledge facilitates new studies and produces new knowledge. We are learning how to break down the northern hardwood forest type into classes suitable for efficient study. Site studies will enable us to stratify areas by estimates of productivity. Tree-grade and growth studies will enable us to sort trees and stands into value classes. And the application of statistics to silvicultural research enables us to design better studies with more confidence in our results.

There are two ways in which data on stand behavior in northern hardwood stands could be used. First, the choice of treatments to apply to stands, and their timing, depends in part upon the way we expect a stand to react. For example, a species with a tendency to stagnate into one crown class would have to be thinned early if large timber were desired.

Second, stand-behavior data could also be used to make silvicultural research more efficient. If we knew how much differentiation normally exists within a stand, we could make better estimates of sample sizes and could devise better tests of cleanings and thinnings. The data would be more sensitive, and the results easier to interpret.

Review of Literature

A Danish forester, L. A. Hauch, in a book he had written with A. Oppermann (1898, p. 101), speculated about the ability of trees in a stand to divide into classes. He called this ability *Spredningsevne* (literal translation: *spreading ability*).[1] The existence of these classes was evident to all foresters. But species seemed to differ in this ability. And this ability to divide into classes seemed to vary with site.

In 1910, Hauch clarified his theory:

> "Spreading ability expresses the stratification into size classes. One could possibly define spreading ability as the ability of a given species, in the same environment and under the same treatment, to develop a large or small number of individuals in the upper and middle height classes from a given number of stems. Thus, a species possesses a larger spreading ability as the number of stems in these height classes is less. It is possible that the difference between the tallest and shortest in a dense stand of a species with a small spreading ability could be as great as that of a species with a large spreading ability but the number of suppressed is less. The middle and upper crown classes are more strongly represented in a species with a weak spreading ability. I cannot relinquish the opinion that there is a correlation between spreading ability and the tendency of a species to develop straight stems and steady growth." [2]

In other words, Hauch claimed that not only did the variances differ in forest stands, but that the distributions were not normal. The way they were skewed depended upon the species.

Lönnroth (1926) studied the structure and development of even-aged Scotch pine stands on three site types in Finland. In addition to determining the average values for a number of stand characteristics, he calculated the variances. Lönnroth was one of the first to test Hauch's hypotheses. He found differences in variation among the site types in height and diameter. At that time many of the statistical tests of significance either had not been devised or were not often applied to biological data.

Lutz (1932) related site quality to stand density in both hardwood and softwood stands. Once the stands had closed and competition had begun, good sites usually had fewer stems per unit area than poor. Presumably the inherent capacity for rapid growth is expressed more fully on the better sites. "These vigorous seedlings develop rapidly and soon overcome their neighbors; dominance is expressed early," he said.

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[1] Translated as *deviation capacity* by Svend O. Heiberg.

[2] Translated by Adrian M. Gilbert.

Lutz reasoned that, on the poorer sites, growth was slower and an early expression of dominance was lacking. This led to a more or less uniform rate of development, and "differentiation into crown classes is delayed." He also said that "competition is not as eliminative" on poorer sites.

In American forestry terminology, expression of dominance usually refers to the tendency of a species to hold a large or small number of trees in the dominant plus co-dominant crown class. This is the way Lutz used the term.

Deen (1933) studied the expression of dominance in white pine in New England. He pointed out that the distribution of numbers of trees by size classes should follow the normal curve. "The more regular the stand," he said, "the more the trees are crowded in relatively few size classes and the weaker the expression of dominance."

Deen measured the standard deviation of diameter as an index of the expression of dominance. He showed a strong correlation between the standard deviation of diameter and other stand features such as density, average radial growth of dominants, standard deviation of height, and standard deviation of crown spread.

Deen defined expression of dominance as "the division into diameter and crown classes resulting from an unequal rate of growth in the trees of a pure, evenaged stand." His concept was almost as broad as Hauch's, but expression of dominance persists solely as a description of crown-class differentiation.

Deen discussed factors that might influence the expression of dominance — inherent characteristics, seed size and origin, site, within-plot age variation, density, weeviling, and silvicultural treatment. He attempted to set a standard of acceptable expression of dominance, which was described as a stand with such differentiation of crown classes that the dominant trees could maintain the largest rate of growth consistent with the development of well-formed crop trees. He found that on the better sites white pine had an acceptable expression of dominance.

Kurth (1946) studied the structure and quality of young evenaged beech stands in Switzerland. He found that the variance of height increased with age. However, the coefficient of variation of height was higher in sapling stands than in young pole stands. Kurth concluded that the stratification into quality classes was not clearly influenced by macrosite. In these young stands the immediate environment dominates the development.

Concept of Stand Differentiation Ability

What emerges here is a concept of *stand* development that attempts to explain the differentiation that is found in pure even-aged stands. I believe that a large part of the difficulty in finding a good expression for the concept lies in the vagueness of what a forester means by a stand. It is easier to tell what a stand is *not* than what it *is*. A stand is not an area classification. Nor is it merely a number of trees growing in proximity. A stand is not a unit of forest management, as a compartment, block, or working circle.

The SAF Forestry Terminology (1958) defines a stand as: "An aggregation of trees or other growth occupying a specific area and sufficiently uniform in composition (species), age, arrangement, and condition to be distinguishable from the forest or other growth on adjoining areas."

Leibundgut has a similar definition.[3]

> "Under stand is understood a part of the forest that differs on the basis of its species composition, its age, its structure, or any other important characteristic; *and therefore is the subject of separate silvicultural planning and handling.*"

I define a stand as a dynamic community of trees characterized by the way it reacts to natural or manmade stimuli. The development of the trees in a stand reflects: (1) each tree's inherent characteristics (genotype); (2) its reaction, as an individual stem, to its environment (phenotype); and (3) the reaction of the trees to each other — a special kind of environmental response.

It should be noted that this composite reaction of trees to each other and to environment or stimuli (treatment) is not the sum of the individual stem reactions. It may be more or it may be less. It is this within-stand-interaction and the fact that the interaction differs from one stand to another that distinguishes a forest stand from an orchard or any other group of trees growing in proximity.

Apple trees in an orchard vary from each other. These differences among apple trees that are due to inherited characteristics are genotypic: those due to reaction of the genotype with environment are phenotypic. It is these kinds of individual variation that have been studied intensively by the geneticists.

---

[3] From lecture notes of Hans Leibundgut, Professor of Silviculture at the Swiss Federal Institute of Technology, Zurich, Switzerland. Italics are the author's.

Trees in a stand express genotypic and phenotypic variation. They also express the reaction of one tree to another. This is the most difficult kind of phenotypic variation to assess because of the peculiar mix of individual interaction and stand interaction effects. Yet, stand reaction is the basis of much silvicultural practice—cleanings, thinnings, and selection-system cuttings.

It is the necessity to assess this all-embracing stand behavior that has led, in part, to difficulty in fitting words to a concept. It is also true that the peculiarities of a stand as a unit of silvicultural treatment have not been generally understood.

Now, when we return to the phenomenon of stand behavior, this ability of a stand to differentiate into crown classes, into diameter classes, and into quality classes, and to vary this ability with species, with age, and with site, we see that a term to describe this idea should include the word, *stand.* For this reason, I propose *stand differentiation ability* (SDA) for this concept. In silviculture, the stand is the unit of differentiation (Toumey and Korstian, 1947).

Conditions of the Study

A study was conducted in the Green Mountains of Vermont, the Taconic Range in Massachusetts-New York, and a small portion of the White Mountains of New Hampshire, to:

1. Test the hypothesis that several northern hardwood species vary in stand differentiation ability (SDA), as measured by diameter, height, crown classes, and quality classes.
2. Test the hypothesis that SDA within and among species varies with age and site.

The study was limited to three species, sugar maple *(Acer saccharum* Marsh.), yellow birch *(Betula alleghaniensis* Britton), and paper birch *(Betula papyrifera* Marsh.). Sugar maple and yellow birch are two of the most prevalent and most valuable hardwood species in northern New England. Paper birch is less common, but highly valued. From observation, it was thought that the three species would provide a range in stand differentiation that would be well suited for study.

The study was limited to natural stands in ages up to 50 years. This facilitated species comparisons. After 50 years, some hardwood stands (paper birch) begin to break up, since the species matures relatively early. Other species, such as sugar maple, are very long-lived. If the species were not comparable by age classes, an extra source of variation would be introduced. Also, as stands age, there is greater variation in density.

Pure stands of each species were sought, to reduce the variation due to species mixture. *Pure* was defined as at least 75 percent of the number of stems or basal area of the major species in the main crown canopy. Normally, there is so much variation in species composition that an extremely large number of samples would be needed just to reduce the variation due to composition. Stem count was used as the basis of purity of stocking in the younger stands with average diameters less than 2 inches; basal area was used as the criterion of purity in stands with an average diameter of more than 2 inches. Basal area is not a meaningful measure of stocking in very young stands.

The stands were on as uniform sites as can be found in this mountainous, glaciated terrain. Aspect, slope percent, rockiness, and drainage were used as important criteria of site in the search for uniformity of conditions.

The stands were even-aged, with a maximum range of ages within the stand of 6 years. Since one hypothesis was that stand differentiation varies within and among species by age, variation in age within a given stand reduces the sensitivity of the test.

Each stand was well-stocked. Within the bounds of age and site differences, the crowns were fully closed and showed no evidences of exceptional mortality.

Stands with sprout clumps were admitted, as long as at least 50 percent of the stems were single. While sprouts have a large initial surge in growth, this advantage disappears after about 10 years in these hardwood stands. A check of the data used in this study revealed no apparent influence of sprouts upon the analysis.

The stands were undisturbed: there were no signs of past cutting, grazing, or fire during the life of the stand. In a few cases, stands with slight mouse or rabbit damage were admitted.

The botanical range of all three species is extensive; for example, paper birch extends across the continent. The study area included such a small part of the natural range of the species that clinal or ecotypic differences are unlikely. On the other hand, the study area was well within the commercial range of the three species, and the results of the study should be applicable on similar sites (climatic, physiographic, and edaphic) in the Northeast.

Methods and Materials

The Areas

The ecological area under study has been defined by Braun (1950) as the New England Section of the Northern Appalachian Highland Division. Here the hardwood forests are found on slopes up to 2,400 feet in elevation. The entire area has been glaciated, and most of the soils are tills. The White Mountains are composed of non-calcareous crystalline gneisses and metamorphic rock. The Green Mountains are composed of schists and some gneisses. A few of the soils are calcareous. Most are podzols or brown podzolics (U.S. Dept. Agr., 1938).

Total precipitation averages 40 inches a year; snowfall 80 to 100 inches a year. The average temperature is about 70° F. in July and about 20° F. in January (U. S. Dept. Agr., 1941). Since most weather data were collected at lower elevations, the averages probably differ somewhat in the mountainous area. In the mountains, one would expect slightly higher precipitation, lower January temperatures, and a shorter frost-free period. But the general climatic picture would not differ from that reported and summarized.

Most of the area had been cut over at least once (Gilbert and Jensen, 1958). The even-aged stands followed clear-cutting for charcoal or fuelwood. Some areas had been burned over.

Other stands had seeded in on old fields as the mountain farms were abandoned. Land-clearing reached its peak in northern New England during the middle of the nineteenth century. Since then, thousands of acres have reverted to forest cover, and the trend continues today.

The Species

The northern hardwood forest is a complex of types found in the colder zones of eastern North America. The major type in the northern hardwood complex is the climax birch-beech-maple type (SAF, 1954). There are numerous associate species, including some conifers.

Sugar maple and yellow birch are two long-lived species that are found in this climax type (Godman, 1957; Gilbert, 1960). Sugar maple also has pioneer characteristics. About half the sugar maple plots in this study were located on abandoned farm land; only one yellow birch plot was found on abandoned land. Paper birch is a shorter-lived species that is rarely found in the climax type (Hutnik and Cunningham, 1961). Of the 15 paper birch plots, 10 were on abandoned land.

Data Collection

The data consisted of measurements on a series of plots, located on a variety of conditions within the scope of the study. Data were taken from 43 plots and 1,175 trees:

Species	*No. trees*	*No. plots*
Sugar maple	15	395
Yellow birch	13	344
Paper birch	15	436
	43	1,175

The plots, all rectangular, varied in area from 3 to 90 milacres, depending upon the average size of trees. Plots were kept small to minimize within-plot variation, but it was desired to measure at least 15 trees of the key species on each plot.

The diameter of all trees larger than 0.50 inches in diameter breast height was measured to the nearest 0.1 inch. Tree heights were measured with either a pole or a Blume-Leiss hypsometer.

All trees were tallied by crown class, using four classes (SAF, 1958) — dominant, co-dominant, intermediate, and overtopped. There was a complete tally of heights for 29 of the 43 plots.

All stems of the key species on each plot were classified by quality into five classes:

1. *Prime tree.*—Admits trees with straight boles; single stem; bole well-pruned for age; lean less than 5 percent; no rotten cull; crown well-shaped on at least 3 sides; branching habit conducive to self-pruning and good crown development.

2. *Good tree.* — Admits crook or sweep up to 20 percent; not more than 2 crooks; lean up to 20 percent; up to 5 percent rotten cull; may be main stem of clump; may contain up to 25 percent of bole in persistent branches; crown well-shaped on at least 2 sides; branching habit conducive to development of relatively clean bole.

3. *Fair tree.* — Admits crook or sweep up to 35 percent, up to 4 crooks; lean up to 35 percent; 15 percent rotten cull; any member of sprout clump; up to one-half bole in persistent branches; acute or coarse branching; may be forked but will produce one 16-foot log below fork.

4. *Poor tree.* — Admits up to 50 percent sweep or crook, any number of crooks; lean up to 50 percent; up to 35 percent rotten cull; may have persistent branches all along stem; may be forked but will produce one 8-foot log below fork.

5. *Cull tree.* — All others.

For most trees, the principal reason for quality classification was recorded (fig. 1). The quality classification was subjective. Since one person classified all the trees, there was greater consistency in application than if several had classified. The weakness of this kind of classification is that a stem in a milieu of poorer-looking stems might be classified differently than if surrounded by equally good or better stems.

Stand age was determined by averaging five increment cores taken at breast height. Five years were added to the average core reading as the estimated time to reach breast height.

Data Analysis

Methodological problems. — In this study we were concerned with stand development as measured in distributions of individual stems. This posed problems in methodology that could not and still cannot be completely resolved.

Before the stand closes, there are differences among the stems. We define the period before the stand closes as that in which there is little or no visible effect of competition for crown space among stems. The stems have not begun to lose their lower branches, and the stands show little or no differentiation into crown classes. Early in the development of the stand, the stems may compete with minor vegetation. Just as the stand closes, however, this minor vegetation usually disappears.

During this period before the stand closes, the observed differences in measurable features are due largely, if not entirely, to the responses of stems as individuals to inherited characteristics and to microsite. What could be measured here is the response of individual stems (dependent variable) to inheritance and microenvironment (independent variables) and to the interaction of these variables.

After the stand closes, individual stem responses are a function not only of inheritance and microsite, but also of competition (Toumey and Korstian, 1947).

Now, stand responses are a function not only of the same factors that influence individual stems, but also of the individual stem responses — and all the interactions. Thus, in measuring stand responses we usually take the dependent variable, the individual stem response, and use it as an independent variable. In a sense what we are doing is ignoring what we do not know about individual stem response.

Statistical tests. — If we are cognizant of these difficulties of studying stand behavior, we can design experiments that are not

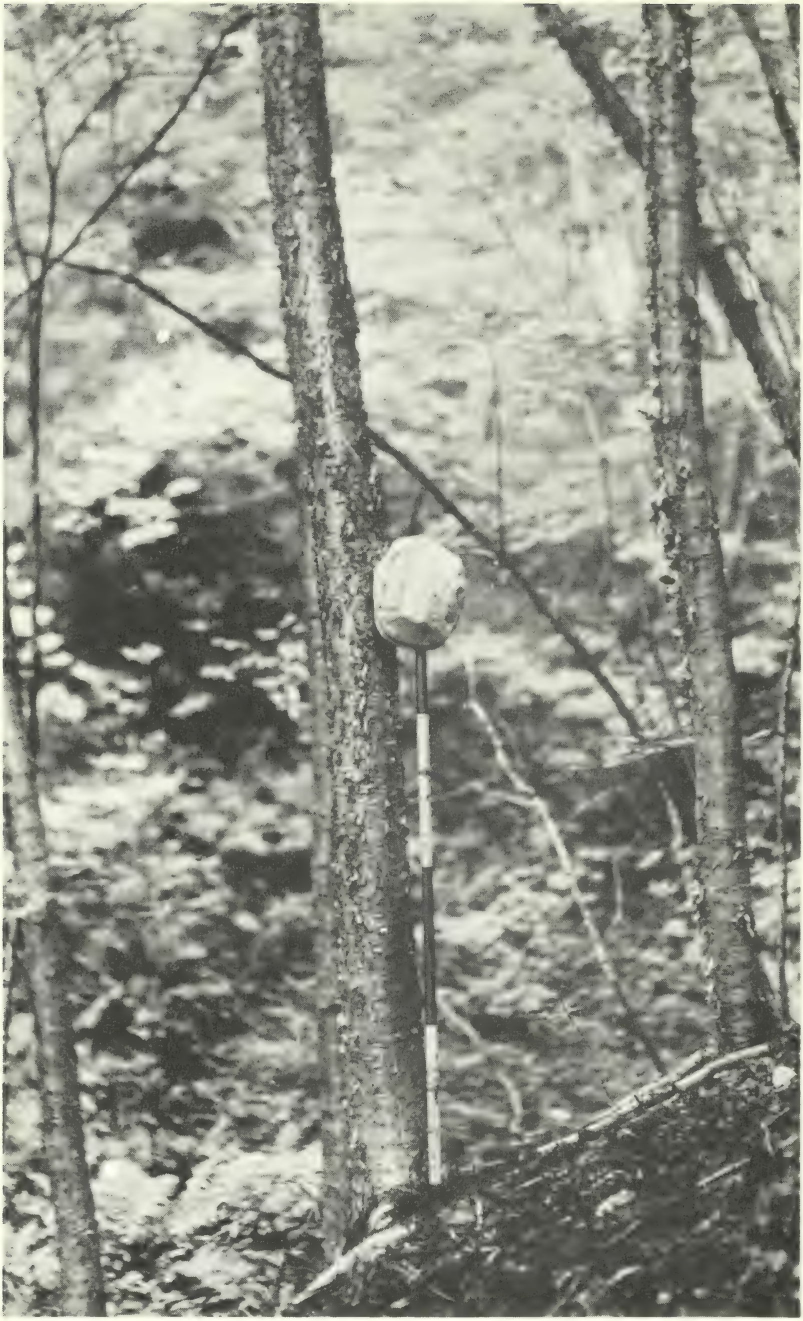

Figure 1. — A prime-quality yellow birch tree, in Mt. Mansfield State Forest, Vermont.

too contrived. And, we can be humble about the conclusions we reach. Since it is difficult to design studies with enough power, we run the risk of accepting false hypotheses — the *beta* error (type II error).

In this study, whenever the null hypothesis was tested by an appropriate statistical test, the probability of rejecting a true hypothesis was set at 10 percent rather than 5 percent.

Differentiation in Stand Diameter

Analysis

Standard deviation of diameter. — In this study, standard deviation of diameter at breast height was treated as a continuous variable. The regression equation was Y= bX. While it is true that the distribution of the standard deviation of diameter may not be normal at each X, this would have little effect upon the tests of significance. These tests are not very sensitive to non-normality. To test if the standard deviation of diameter of each species is related to age, the significance of the regression coefficient, b, was tested by the *t* test, according to Snedecor's formula for ratio regression.

Results

Standard deviation of diameter. — Stands of these three species differentiate more in diameter as they increase in age. The standard deviation of diameter, by which the differentiation was measured, increases at least 0.04 inch a year for all species (fig. 2). This is the same trend that Meyer (1930) found by using stand diameter as the independent variable.

Since the *t* tests revealed significant regression coefficients, "b", this relationship between age and standard deviation of diameter is statistically significant (table 1).

Species comparisons. — There remained the hypothesis that the species differ in differentiation of diameter. The null hypothesis of equal variance among all species was rejected (table 9). However, sugar maple and yellow birch had variances about the regression line that might not differ significantly.

Subsequent *t* tests showed that, though the variances in the standard deviation of diameter for sugar maple and yellow birch did not differ significantly, the slopes of the regression lines did differ enough to be significant.

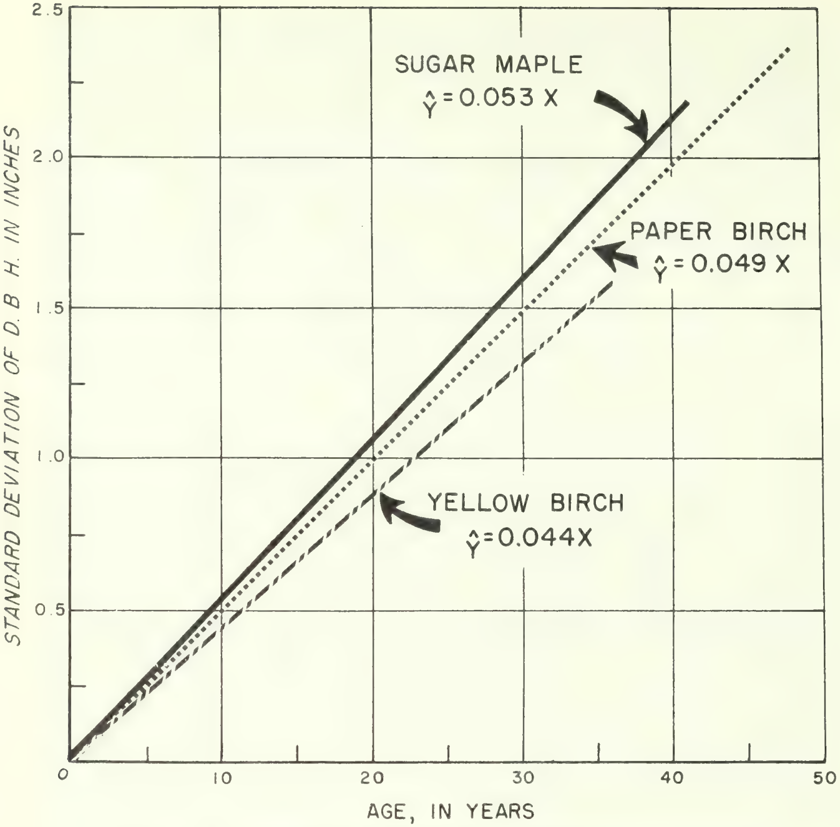

Figure 2. — Species compared for standard deviation of stand diameter in relation to age.

So far, we have learned that the three species do show differentiation in diameter, which increases with age, and that the differentiation is not the same for all species. We should know something about actual diameter increases to learn if this differentiation is large or small in relation to diameter increment.

Coefficient of variation. — The coefficient of variation is a ratio that could provide a more meaningful comparison of differentiation in diameter among species. It is the ratio of the standard deviation to the mean. Since the plots were of different ages, provision must be made for variation due to age in making species comparisons by the coefficient of variation.

Estimates of the standard deviation of diameter for various ages were available from the regressions discussed in the previous section.

Similar estimates for mean diameter at various ages were determined by ratio regression (variance was not homogeneous), with the regression line going through the origin. The equation was of the form $Y = bX$ (fig. 3). It was found that sugar maple had the least increase in average diameter with age (table 2). Tests showed that the regression lines for the three species differ significantly (table 9).

With the two sets of regression data, one for standard deviation and one for mean diameter, the coefficient of variation at various ages can be determined. At the mean age for each species, coefficients of variation for each species were:

Species	*Mean age (years)*	*Mean s (inches)*	*Mean d.b.h. (inches)*	*Coefficients of variation (percent)*
Sugar maple	26.3	1.40	2.25	62.6
Yellow birch	26.5	1.17	2.77	42.2
Paper birch	29.1	1.45	4.50	32.2

An average coefficient of variation (CV) for all ages can also be computed for each species:

CV = (Regression coefficient b of standard deviation of d.b.h. over age) / (Regression coefficient b of average d.b.h. over age) × 100.

Note that on the basis of standard deviation alone, an absolute measure, yellow birch had the least variation in diameter ($b = 0.044$). However, with the coefficient-of-variation ranking, a measure of variation relative to the mean diameter, paper birch had the lowest ratio (32 percent).

Table 1.—Analysis of data for standard deviation of stand diameter

Species	Number of plots	Range of ages, years	Regression equation[1]	90-percent confidence interval[2]	*t* value
Sugar maple	15	17-41	$Y = 0.053X$	0.040 - 0.065	7.24***
Yellow birch	13	17-36	$Y = 0.044X$	0.038 - 0.050	13.72***
Paper birch	15	8-48	$Y = 0.049X$	0.034 - 0.064	5.67***

[1] Y = standard deviation of d.b.h.; X = age.

[2] Standard deviation/year.

*** = Very highly significant.

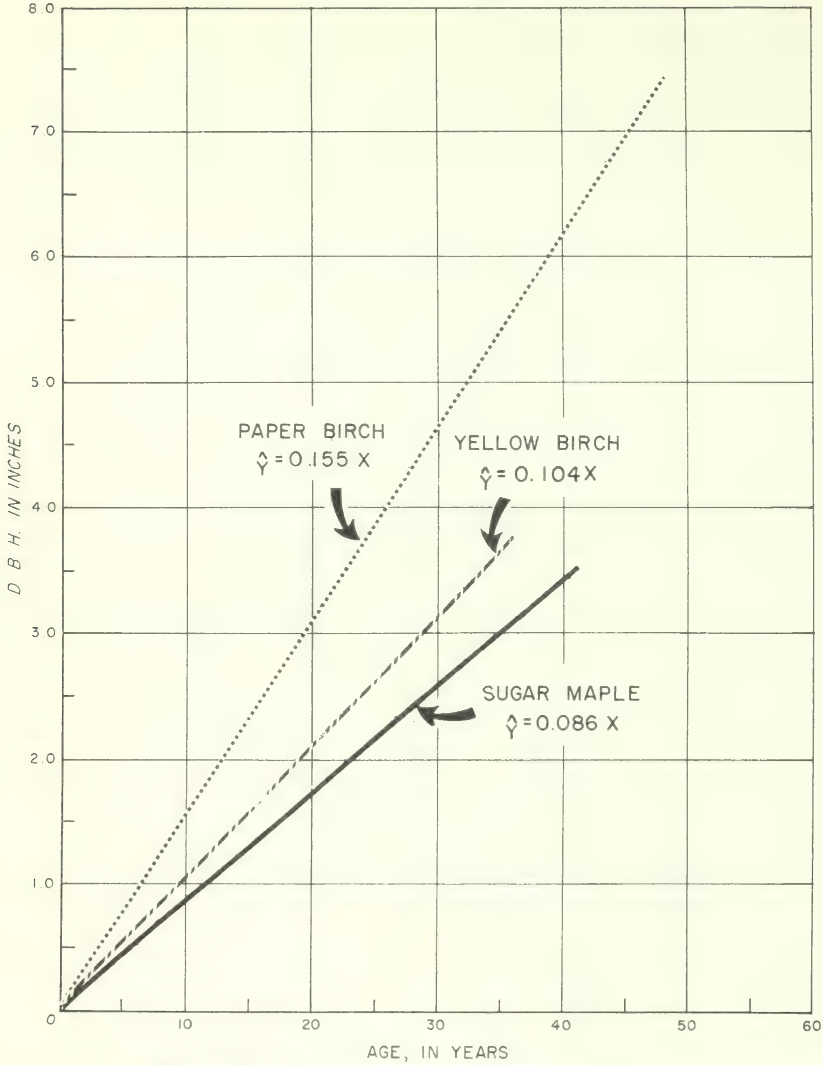

Figure 3. — Average stand diameter in relation to age; species comparisons.

Hauch (1905) had stated that *Spredningsevne* and shade tolerance were not directly related. Sugar maple is a very tolerant species, and it did have the largest standard deviation. But yellow birch, intermediate in shade tolerance, had the least differentiation in diameter. Paper birch, an intolerant species, ranked next to sugar maple in diameter differentiation. However, when ranked by co-

Table 2.—Analysis of data for regression of average diameter breast height over age

Species	Number of plots	Range of ages, years	Regression equation[1]	90-percent confidence interval[2]	*t* value
Sugar maple	15	17-41	$Y = 0.086X$	0.074 - 0.098	12.19***
Yellow birch	13	17-36	$Y = 0.104X$	0.093 - 0.115	16.78***
Paper birch	15	8-48	$Y = 0.155X$	0.133 - 0.176	12.76***

[1] Y = average d.b.h.; X = age.

[2] Average d.b.h./years.

efficient of variation, shade tolerance and standard deviation of d.b.h. coincided. We still lack the knowledge to sort out these interactions.

In tests of statistical significance, the species do differ. Yet we do not know if these differences, in themselves, are large enough to influence response to silvicultural treatment. Interpretation must wait until the results of the other tests are considered.

Differentiation in Total Height

Analysis

Differentiation in total height of stands was analyzed by methods similar to that used for stand diameter. Total height was treated as a continuous variable and related to age. The regression equations were of the form $Y = bX$. Data for the height analysis were available for fewer plots than for diameter.

Species	*No. plots*	*No. trees*
Sugar maple	11	297
Yellow birch	7	185
Paper birch	11	368

However, these data were sufficient to fit a regression line with one independent variable and to make tests for significance of the regression coefficient, b.

Results

The only significant regression coefficient of standard deviation of stand height over age was for sugar maple:

Species	*No. plots*	*Range of ages (years)*	*t value*
Sugar maple	11	17.41	3.38*
Yellow birch	7	20.30	1.22
Paper birch	11	23.48	1.41

These data indicate that within the range of ages tested, for both yellow and paper birch, SDA in height was not significantly dependent upon age. For paper birch, the regression coefficient was negative, indicating an inverse relationship. In other words, as paper birch stands grow older there is a tendency for less variation in height.

For the stands included in this analysis, factors other than age may have a greater effect upon differentiation in total height. Only for sugar maple was there a significant correlation between standard deviation of height and age.

The paper birch data showed an interesting trend that indicated a reduction in height differentiation with increase in age. This contrasts with sugar maple and yellow birch, where the tendency was for increased differentiation with age. It is possible that the analysis of distribution into crown classes will clarify the analysis of height relationships.

Differentiation into Crown Classes

The Choice of Test

In this analysis, we were interested in differences in the ability to differentiate into crown classes. In other words, we were dealing with a discrete variable.

The null hypotheses were that: (1) species do not differ in the ability to maintain stems in the upper crown classes; and (2) within and among species, SDA does not vary with site and age.

We were interested in counts, not in normal distributions. Since crown classes, site classes, and age classes are discrete variables, the chi-square test for contingency tables was appropriate.

The Choice of Classes

The variables — site and age — were broken into enough classes to permit the testing of the hypotheses and still have biological meaning. For testing the differentiation into crown class and quality class, age was divided into two classes — 0 to 26 years, and 27 years and older. At about 25 years, most stands of these hardwood species are at the transition from cleanings to thinnings;

there is greater confidence in the selection of crop trees. The actual break at 26 years was made to permit about equal numbers of plots in each class for each species. Additional age classes would have weakened the chi-square analyses by reducing the expected numbers of observations per cell.

Similarly, site was broken into two classes: good and poor. Site-index curves for these species do not go below 20 years (Curtis and Post, 1962), and such curves are less reliable for young stands.

Site class was computed by ratio regression, height of the five tallest trees on the plot over age, with the regression line extending from the origin, $a = 0$. All plots that fell above the regression line were site class 1; those below were site class 2.

Three crown classes were used: dominant plus codominant, intermediate, and overtopped.

Analysis

For the chi-square analysis, each tree on a plot was treated as an independent count to be placed into a particular cell. First the plots were sorted by key species, age class, and site class. Then each stem of the key species was placed into its crown class-age class-site class-species cell. When this was done, the plot identity was lost. In other words, all plots of a given age class-site class-species cell were considered as samples of the same population whose data could be pooled. This assumption underlies all succeeding tests of hypotheses, in quality classes as well as crown classes.

It is important that when the plots were chosen there was no bias in selecting plots of a particular age class or site class. The fact that there were not equal numbers of plots in age and site classes had no effect upon the analysis.

For ease of analysis, the chi-square test was used to test hypotheses of independence in two-way contingency tables.

Results

Sugar maple. — When each site class was held constant in turn, the distribution of sugar maple into crown classes was independent of age classes (table 10). However, when age classes were pooled and the two site classes were compared, the null hypothesis of independence was rejected. On both sites less than 30 percent of the stems were in the dominant-plus-codominant crown class (table 3).

Table 3.—Distribution of sugar maple stems into crown classes by age class and site class, data pooled when possible

Item	Crown class			Basis
	Dominant and codominant	Intermediate	Overtopped	
	Percent	*Percent*	*Percent*	*No. stems*
Site class 1;				
age classes 1 & 2	29.2	20.3	50.5	216
Site class 2;				
age classes 1 & 2	23.1	14.7	62.2	251
Age class 1:				
Site class 1	31.8	22.0	46.2	132
Site class 2	22.6	12.8	64.6	164
Age class 2:				
Site class 1 & 2	24.6	18.1	57.3	171

When age class was held constant, the distribution into crown classes was independent of site in the older stands but not in younger stands (table 3). With one exception the tests showed fewer than 30 percent dominants and codominants when age was held constant; it was 32 percent in the excepted case.

Yellow birch. — When each site class was held constant, the distribution of yellow birch into crown classes was independent of age classes (table 10). When age classes were pooled and the two site classes were compared, the null hypothesis of independence was rejected. On the better sites, 42 percent of the stems were dominant or codominant; on poorer sites, only 28 percent (table 4).

At all age classes, there was interaction between crown class and site class (table 4). More than 40 percent of the stems were dominant or codominant on site class 1, and less than 30 percent on site class 2, regardless of age class.

Paper birch. — On site class 1, the distribution of paper birch into crown classes was independent of age classes (table 10). On site class 2, the null hypothesis of independence of crown class and age class was rejected. Here there was a larger proportion of overtopped trees in the younger stands.

Regardless of interaction, on site class 1 more than 70 percent of the paper birch stems were dominant and codominant in all instances. On site class 2, dominants were 31 percent in younger stands and 57 percent in older (table 5).

At neither age class was the distribution of paper birch into crown classes independent of site. In the younger stands, there was a much greater proportion of the stems in the dominant-plus-codominant class on the better sites. These made the largest contribution to chi-square. In stands over 27 years old, it was the large proportion of overtopped trees on poorer sites that made much of the contribution to chi-square.

Species comparisons. — Strictly speaking, valid tests of independence among species with pooled data are only for those cells where the null hypotheses of independence for comparable variables were accepted.

In these tests, we noted that on site class 1 the null hypotheses of independence of crown class and age class were accepted for each of the three species. Then the species were compared by pooling age class and testing species x crown class in a contingency table. The null hypothesis of independence was rejected (table 11). On site class 1, the species did differ significantly in differentiation into crown classes. On these better sites, 75 percent of the paper birch stems were dominant or codominant; so were 42 percent of the yellow birch and 29 percent of the sugar maple.

On most of the other individual tests among and between species, the null hypotheses of independence were rejected (table 11).

Table 4.—Distribution of yellow birch stems into crown classes by age class and site class, data pooled when possible

Item	Crown class			Basis
	Dominant and codominant	Intermediate	Overtopped	
	Percent	*Percent*	*Percent*	*No. stems*
Site class 1;				
age classes 1 & 2	42.5	12.3	45.2	212
Site class 2;				
age classes 1 & 2	27.9	15.8	56.3	222
Age class 1:				
Site class 1	46.9	10.9	42.2	64
Site class 2	29.3	14.7	56.0	150
Age class 2:				
Site class 1	40.5	12.8	46.7	148
Site class 2	25.0	18.1	56.9	72

Table 5.—Distribution of paper birch stems into crown classes by age class and site class, data pooled when possible

Item	Crown class			Basis
	Dominant and codominant	Intermediate	Overtopped	
	Percent	*Percent*	*Percent*	*No. stems*
Site class 1;				
age classes 1 & 2	75.3	14.5	10.2	117
Site class 2;				
Age class 1	31.1	22.2	46.7	167
Age class 2	57.3	20.7	22.0	82
Age class 1:				
Site class 1	78.3	8.7	13.0	23
Age class 2:				
Site class 1	74.5	15.9	9.6	94
Site class 2	57.3	20.7	22.0	82

From the results of all the individual tests we may infer that the three species differ in differentiation into crown classes.

Discussion

The data for the three species indicate the relative effects of site and age upon the distribution into crown classes.

Site appears to exert more influence than age in the distribution. The drop in the proportion of stems in the dominant and codominant class is much greater from site class 1 to site class 2 than from younger to older age classes.

For both sugar maple and yellow birch, when site class was held constant, age class had no significant effect upon crown class distribution. On the poorer sites of paper birch, there were relatively more stems in the main crown canopy in older stands than younger. Normally, the reverse trend would be expected.

These observations confirm those made in the previous chapter on differentiation in stand height. It may be recalled that sugar maple was the only species with a significant increase in standard deviation of height with increased age. For paper birch, the trend was reversed.

Köstler (1952) made similar observations concerning thickets in Germany. He found several patterns of crown differentiation, which he attributed partially to tolerance differences among species.

On the better sites, the three species differed much more than in any other class. Even though present site-index studies have been unable to measure site index in young hardwood stands, site differences are present. It is likely that the crown-differentiation pattern is a strongly inherited species characteristic and that it is modified by site.

The results of these tests of differentiation into crown classes suggest that if crown classes are to be used effectively in describing stands, their connotations should be revised. It now seems likely that different species, at different ages, on different sites, tend to follow different crown-class patterns. For example, if three out of four paper birch stems on site class 1 are dominant or codominant (table 5), knowledge that a stem is codominant in such a stand tells us little about its expected behavior in comparison with its neighbors. The same codominant stem on site class 2 and age class 1 would be among 3 out of 10 in such a position, and we might expect it to develop differently.

Differentiation into Quality Classes

Analysis

Each stem of the three species under study had been classified into one of five quality classes. The classes were composites of visible stem and crown characteristics. The hypotheses to be tested were:

1. The species differ in SDA for quality classes.
2. The differentiation into quality classes varies by site and age within and among species.

Here, as with crown classes, we were not interested in normal distributions, and the variables were discrete (counts). Hypotheses of independence in contingency tables were tested with the chi-square test.

Results

In the individual species tests, interaction between site or age and quality was prevalent.

Individual species tests. — For sugar maple, the only acceptance of the null hypothesis of independence was when age class 2 was held constant in the test of site quality x quality class (table 12).

The results showed a generally low proportion of prime-plus-good stems and a high percentage of culls for sugar maple (table 6).

For yellow birch, interaction between quality and age or site was the rule. Independence was accepted only in a test of age class x quality class, when site class 1 was held contant (table 12). Yellow birch, too, had a low proportion of stems in the prime and good quality classes the proportion of cull stems was high (table 7).

In general, the results of the quality-class tests were the same for paper birch as other species. Except when site class 1 was held constant, the null hypothesis of independence was rejected in the chi-square tests (table 12). Paper birch was found to have a high proportion of good growing stock: about one-third of its stems were prime-plus-good quality (table 8).

Species comparisons. — In the formal species comparisons, various combinations of age class and site class were held constant. Species x quality classes were tested in two-way tables. Whenever all three species were tested, the null hypothesis of independence was rejected (table 13). In several instances, however, sugar maple and yellow birch were found to have similar distributions into quality classes. Although the differences among species were too large to be random, they all showed the same trend on site class 2. That is, in the older stands there was a higher proportion of prime-plus-good trees than in stands under 26 years, on the poorer sites.

Table 6.—Percentage distribution of sugar maple stems into quality classes by age class and site class, data pooled when possible

Item	Quality class					Basis: No. stems
	Prime	Good	Fair	Poor	Cull	
Site class 1:						
Age class 1	8	17	24	19	32	114
Age class 2	0	13	31	18	38	84
Site class 2:						
Age class 1	2	5	19	28	46	156
Age class 2	4	14	30	27	25	83
Age class 2;						
Site class 1 & 2	2	14	30	22	32	167

Table 7.—Percentage distribution of yellow birch stems into quality classes by age class and site class, data pooled when possible

Item	Quality class					Basis: No. stems
	Prime	Good	Fair	Poor	Cull	
Site class 1;						
Age classes 1 & 2	4	11	38	22	25	211
Site class 2:						
Age class 1	3	8	18	21	50	151
Age class 2	6	18	22	20	34	71
Age class 1;						
Site class 1	3	6	38	22	31	64
Age class 2;						
Site class 1	4	13	38	23	22	147

In the crown-class comparisons, all species showed little or no downward trend in the proportions of dominants and codominants with increased age. Since almost all the better quality trees are found in the main crown canopy, one would expect that the proportion of higher quality trees would have remained almost as high in the older age class as the younger. But why should it increase? Apparently, the slower rate of growth on the poor sites favors some attributes of good quality — clean bole, fine branching.

Discussion

From the data analysis, we can make several deductions concerning the hypotheses on quality relationships. We can say that the SDA into quality classes varies by age and site classes within and among species.

Since there is so much interaction, a clear-cut comparison cannot be made among species as a whole. There is no statistical validity, but the quality-class distributions, in percent, can be tabulated:

Species	*Prime*	*Good*	*Fair*	*Poor*	*Cull*
Sugar maple	3	12	25	23	37
Yellow birch	4	11	29	21	35
Paper birch	7	25	37	23	8

Sugar maple and yellow birch are similar in differentiation into

Table 8.—**Percentage distribution of paper birch stems into quality classes by age class and site class, data pooled when possible**

Item	Quality class					Basis: No. stems
	Prime	Good	Fair	Poor	Cull	
Site class 1;						
Age classes 1 & 2	10	23	51	10	6	116
Site class 2:						
Age class 1	6	19	24	46	5	93
Age class 2	4	34	32	17	13	82
Age class 1;						
Site class 1	9	27	41	23	0	22
Age class 2;						
Site class 1	11	21	54	7	7	94

quality classes; they average about 15 percent prime-plus-good quality trees.

It may be recalled that paper birch had the largest proportion of stems in the dominant-codominant crown class. The two distributions — crown class and quality class —are undoubtedly related, but the relationship is not necessarily cause and effect.

To learn more about the relationship of the two distributions, a series of species-quality class tests of independence were run for dominant-plus-codominant stems only. Age class or site class was held constant in turn. In all but one test, the null hypothesis of independence was accepted. The general percentage distribution of dominants and codominants with age classes and site classes pooled was:

	Quality Class				
	Prime	*Good*	*Fair*	*Poor*	*Cull*
All species	11.5	30.0	44.3	10.8	3.4

This distribution of 42 percent of dominants and codominants as prime-and-good-quality trees represents almost a threefold increase for sugar maple and yellow birch over the distribution of quality among all crown classes.

Table 9.—Tests of hypotheses of equal variance of β

Item[1]	Differentiation of stand diameter analysis			Average diameter age analysis		
	SM	YB	PB	SM	YB	PB
Number of plots	15	13	15	15	13	15
b	0.052540	0.044046	0.049140	0.085933	0.103846	0.154666
S_b^2	$1.38(10^{-5})$	$1.03(10^{-5})$	$7.0(10^{-5})$	$4.97(10^{-5})$	$3.83(10^{-5})$	$1.468(10^{-4})$
$Sy.x^2$	$2.07(10^{-4})$	$1.339(10^{-4})$	$1.05(10^{-3})$	$7.455(10^{-4})$	$4.979(10^{-4})$	$2.202(10^{-3})$
F_{max}[1]		1.34	6.76**		1.30	3.83*
t^2		6.49**			7.16**	

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[1] F_{max} applies to S_b^2. t applies to tests between regression coefficients.

Table 10.—Differentiation into crown classes, tests of independence

Species	Variables held constant	Variables tested	Chi-square value	Degrees of freedom	Significance
Sugar maple	Site class 1	Age class x crown class	2.5	2	NS
	Site class 2	Age class x crown class	1.7	2	NS
	Age class 1	Site class x crown class	10.4	2	S
	Age class 2	Site class x crown class	([1])	2	NS
Yellow birch	Site class 1	Age class x crown class	.7	2	NS
	Site class 2	Age class x crown class	.7	2	NS
	Age class 1	Site class x crown class	6.1	2	S
	Age class 2	Site class x crown class	5.2	2	S
Paper birch	Site class 1	Age class x crown class	.1	[2]1	NS
	Site class 2	Age class x crown class	8.3	2	S
	Age class 1	Site class x crown class	19.2	2	S
	Age class 2	Site class x crown class	6.8	2	S

[1] Less than 0.05.
[2] Classes combined.

Table 11.—Differentiation into crown classes, species comparisons, tests of independence

Variables held constant	Variables tested	Chi-square value	Degrees of freedom	Significance at 90% level
Age class 1, Site class 1	All species x crown classes	18.5	4	S
Age class 1, Site class 2	All species x crown classes	12.0	4	S
Age class 1, Site class 2	SM and YB x crown classes	2.6	2	NS
Age class 2, Site class 1	YB and PB x crown classes	37.2	2	S
Age class 2, Site class 2	YB and PB x crown classes	21.9	2	S
Site class 1, ages pooled	All species x crown classes	74.8	4	S
Site class 1, ages pooled	SM and YB x crown classes	10.2	2	S
Site class 2, ages pooled	SM and YB x crown classes	1.9	2	NS

Table 12.—Differentiation into quality classes, tests of independence

pecies	Variables held constant	Variables tested	Chi-square value	Degrees of freedom	Significance at 90 level
	Site class 1	Age class x quality class	8.3	4	S
gar maple	Site class 2	Age class x quality class	15.2	4	S
	Age class 1	Site class x quality class	11.4	4	S
	Age class 2	Site class x quality class	4.4	4	NS
	Site class 1	Age class x quality class	3.1	[1]3	NS
llow birch	Site class 2	Age class x quality class	8.4	[1]3	S
	Age class 1	Site class x quality class	10.2	[1]3	S
	Age class 2	Site class x quality class	10.7	[1]3	S
	Site class 1	Age class x quality class	15.0	2	NS
er birch	Site class 2	Age class x quality class	7.1	[1]3	S
	Age class 1	Site class x quality class	1.3	2	S
	Age class 2	Site class x quality class	16.7	4	S

Quality classes 1 and 2 were pooled to raise the expected number in each cell to at least 5. In some cases, classes 4 and 5 were also combined.

Table 13.—Species comparisons, differentiation into quality classes, tests of independence

Variables held constant	Variables tested	Chi-square value	Degrees of freedom	Significance at 90% level
Site class 1,			4	NS
ages pooled	YB and PB x quality classes	35.5	8	S
Site class 2,	All species x quality classes	63.4	[1]3	S
age class 1	SM and YB x quality classes	2.7		
Site class 2,	All species x quality classes	18.1	8	S
age class 2	SM and YB x quality classes	3.3		
Age class 1,	All species x quality classes	24.2	[1]3	S
site class 1	SM and YB x quality classes	7.5		
Age class 1,	All species x quality classes	63.4	4	S
site class 2	SM and YB x quality classes	6.5	8	S
Age class 2,			4	NS
site class 1	All species x quality classes	49.6	8	S
Age class 2,			4	NS
site class 2	YB and PB x quality classes	10.7	8	S

[1] Classes combined to raise expected number to at least 5.

Summary and Discussion

A mass of data has been collected, compiled, and analyzed to learn—

1. If sugar maple, yellow birch, and paper birch vary as to stand differentiation ability in diameter, in height, in crown-class distribution, and in qualty-class distribution.
2. If this differentiation, both within and among species, is related to age and site.

Differentiation in Stand Diameter

The data on standard deviation of stand diameter provide an example of the difference between significance and importance. Statistical significance has the support of mathematical theory, but it is still subject to the vagaries of chance. Importance is interpreted by people, and it is shaped by the particular values of the moment.

Stand differentiation ability varies among the three species. All species showed an increase in standard deviation of diameter of 0.04 to 0.05 inch a year. The greatest difference between species was 0.009 inch of diameter a year, certainly small; but the tests were sensitive enough to mark the differences as significant. But, the importance of these statistics to a practicing forester is another matter.

Differentiation in Stand Height

The results of the height analyses are unexpected. From the previous diameter analyses, it seemed possible to induce a more general theory concerning differentiation in stands: that as stands grow older the differentiation of many measurable attributes would increase. Other attributes might include diameter at 17 feet and total height.

But the height analyses preclude such a general theory, at least until we have more knowledge. The hypotheses were not supported by the statistical tests. The null hypotheses of no differences in differentiation in total height were accepted. Sugar maple was the only species of the three that showed a significant increase in differentiation of total height with increased age. The general tendency was the same for yellow birch, but the regression coefficient was not significant. However, for paper birch, the trend, although not significant, was the reverse — less differentiation with increased age.

The trend of paper birch is quite different from that of the other two species. The slope of the regression line was so slightly negative that it would take many more observations to detect statistical significance.

We can also infer that in these young natural stands the competition for light has a much greater effect upon height differentiation than upon diameter. The denseness of the stands tends to reduce the height differentiation. In stands of lesser density, more light would filter through the crown canopy, and we would expect increased differentiation in height. Thus it seems that the results of the height analyses are due not to a restricted range of ages, but to a restricted range in stand density. The reader may recall that the study was limited to well-stocked stands.

It must be noted that site was not included in the differentiation of stand-height analyses. Site does influence the rate of height growth and thus total height at given ages. But the height analyses showed homogeneous variance among the species (at the mean). Stratification by site would serve to reduce the variance and make the species even more homogeneous. Tests for the effects of site were left for the crown-class analyses.

Differentiation Into Crown Classes

The crown-class analyses included the effects of age and site upon the distribution of stems into crown class for each species and for comparisons among species.

Crown-class distributions are still somewhat concerned with the height parameter. So much of the theory of silviculture and of stand mensuration is related to crown-class strata that a study of stand development would be incomplete without an investigation of crown classes. Hauch's original hypothesis was that species differ in their distribution into crown classes.

In general, the results support Hauch's hypothesis: these three species do differ in their distribution into crown classes. Furthermore, these distributions are related to site, as Hauch had suggested. They also vary with age, within the limits of the ages studied, but to a lesser extent.

Presumably, if a species had a tendency to crowd many stems into the dominant and codominant crown classes, the stands would grow very slowly. This occurs commonly with lodgepole pine

(*Pinus contorta* Dougl.) and with other species on very poor sites. In other words, the tendency towards reduced crown differentiation is strongly inherited in some species and is due mostly to environment in others.

For paper birch, the distribution into the dominant and codominant crown class reached as high as 75 percent under certain age class-site class conditions, and averaged more than 50 percent. However, we have also seen that paper birch maintained the most rapid increase in average stand diameter within the age limits of the study material. Thus, we conclude that a proportion of dominants and codominates as high as 75 percent in itself is not a danger signal for reduced growth in paper birch.

The opposite situation, a low percentage of stems in the upper crown canopy, has implications for those interested in tree quality. This will be discussed later.

The question might arise as to why the species should differ in crown-class distribution and not in differentiation of total height. A partial answer is that the two distributions differ. Total height distribution may or may not be normal; crown class is binominal or multinomial.

Then, it appears that the crown class into which a species crowds its stems has little or no effect upon the variance of total height. Paper birch, with 51 percent of its stems in the dominant and codominant crown class, had a variance of 6.14; sugar maple, with 57 percent of its stems suppressed, had a variance of 14.89. Still the variances of all the species at their mean heights, were homogeneous.

There are also differences in total-height and crown-class observations. Total height is an absolute measurement and is subject to less error than an estimate of crown class, which is partially subjective. All in all, there are apparent inconsistencies for which proven explanations are lacking.

If the general objective of thinning were to shift the volume growth to selected trees in a stand, what, how much, and how often something should be done depends upon the species.

Differentiation into Quality Classes

In young hardwood stands, many tree-quality characteristics — relative length of clear bole, branching habit, and fullness of crown — are closely related to a tree's crown classification. These help provide estimates of future stem quality. It follows, therefore, that interpretation of the quality-class data relies heavily upon the crown-class analyses.

Many aspects of the original hypotheses concerning quality classes were sustained. While all three species do not differ in differentiation of quality classes, paper birch differs significantly from sugar maple and yellow birch. It has twice as many prime and good quality stems, on the average, as sugar maple and yellow birch. And these differences between paper birch and the other two species are related to age and site.

There is consistent interaction between site or age and quality-class distributions, and few definite patterns were found. In each species, the cell that tended to have one of the highest concentrations of prime-plus-good stems was age class 2-site class 2. The only biological inference here is that the slower growth of stems in this cell favors some of the attributes of better quality stems.

A special analysis of the quality-class data for dominant and codominant stems only showed that here the species were remarkably alike in quality-class distribution. Thus most of the differences in quality-class distributions among species are directly related to the distributions into crown classes.

Both sugar maple and yellow birch had only 15 percent of their stems in the better quality classes. There was roughly a 1:2 ratio of better quality stems to dominant-plus-codominant stems:

Species	*Ratio of prime-plus-good stems to dominant-plus-codominant (percent)*
Sugar maple	58
Yellow birch	43
Paper birch	63

It is true that by merely removing poorer quality stems from the upper crown canopy, the ratio would be raised. But this would not provide any more better-quality stems. The problem for the silviculturist interested in growing high-quality hardwoods is to increase the actual numbers of better quality stems in the upper crown canopy.

There are several inferences from this study for those interested in growing hardwoods for quality in even-aged stands. Under natural conditions, there are not many prime and good quality stems of sugar maple and yellow birch to favor in silvicultural treatments. The better quality stems are found almost exclusively in the main crown canopy. This is where treatment would be centered; increases in the number of better quality stems are directly related to the maintenance of stems in the main crown canopy.

Sugar maple maintained the lowest percentage of dominants and codominants; yellow birch was next.

While the trend in main crown-class distribution with increased age was slightly downward for sugar maple and yellow birch, offhand this would not appear enough to justify intervention to improve quality distribution. But one must recognize that the youngest sugar maple and yellow birch stands sampled were 17 years old. By this age, the proportion of dominant and codominant stems may have already reached levels so low that it would be difficult to maintain enough better quality stems.

This sustains the earlier recommendations of Schädelin (1942) to start cleanings as soon as the stands close. However, for a species with a differentiation pattern like that of paper birch, the necessity for early intervention is greatly reduced (for the objective of altering crown-class distribution).

This situation has been discussed frequently in European literature in recent years (Köstler, 1952; Kunz, 1953; Kurth, 1946; Schädelin, 1942; Van Migroet, 1956). The general findings are that stems in the intermediate crown class cannot be brought up to codominant or dominant positions; but by early intervention, a greater percentage of trees can be held in the upper crown canopy.

Limitations

From the data gathered and analyzed in this study, we can allude to the complex inherited-environmental relationships. We now have a predictive ability, with no indication of the universality of the statistics, and little understanding of the underlying factors.

Our interest in measuring stand differentiation ability in young forests comes from inferences we may wish to draw concerning the future development of the stands. We are not concerned here with end use of the trees in the stand. Rather, we are concerned with prediction of the future differentiation in the stand, with estimates of how the stand might respond to treatments to meet various objectives, and with understanding of the factors at work.

The predictive ability may suffice for the present state of silvicultural practice. But, for the researcher, this predictive ability is insufficient. Questions are left unanswered, interactions are unexplained.

New knowledge will come from additional stand studies. In such studies there should be control of the variables — plots replicated in site, age, density, growing stock. The stand studies will be enhanced by individual stem analyses, by studies of the heritability of characteristics, and by physiological studies of tree and stand growth.

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Growth of
Yellow Birch
in a Podzol Soil

by Merrill C. Hoyle

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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

Growth of
Yellow Birch
in a Podzol Soil

■

The Author--

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Introduction

YELLOW BIRCH (*Betula alleghaniensis* Britton) has been described as a very sensitive tree that adapts poorly to changes in environment (Gilbert 1960). In New Hampshire, old-growth yellow birch stands have displayed high mortality and low production (Filip *et al* 1960). And in second-growth stands, the percentage of yellow birch has been found to decline under all levels of stocking examined. Furthermore, this species had the highest mortality and made only poor to fair ingrowth in studies conducted over a 25-year period on the Bartlett Experimental Forest in New Hampshire (Leak 1961). Besides making poor growth, yellow birch has been beset by several maladies, especially post-logging decadence (Hall 1933) and dieback (Hawboldt 1947).

Little is known about the causes of this characteristically poor performance of yellow birch. Several aspects of the problem have been examined in the past, but more recently forest soils have been studied for possible clues. Of particular interest is the effect of rooting depth on the development of birch (Pomerleau and Lortie 1962).

Yellow birch generally develops a shallow root system on forest soils in the Northeast. This is understandable where hardpans, bedrock, or water tables are found close to the surface; but in deeper and well-drained soils the superficial rooting is more difficult to explain.

Redmond (1954) observed, after excavating yellow birch roots, ". . . that they develop in an area or fail to do so because of isolated edaphic peculiarities in their immediate vicinity . . ." In subsequent pot experiments, he discovered that yellow birch seedlings developed extensive roots in loam but not in sand. He felt that higher nutrient content of the loam was responsible.

Tubbs (1963) and Winget *et al* (1963) obtained similar results for yellow birch seedlings variously planted in humus and mineral soils collected under hemlock-hardwood stands in the Lake States. Seedlings developed well in humus, but only slightly or not at all in mineral soil. Tubbs tried unsuccessfully to induce rooting in the mineral soil by adding a commercial fertilizer solution (7-6-19). And I experienced similar difficulties in attempts to grow yellow birch seedlings in mineral soils for purposes of soil-fertility evaluation.

Therefore it was decided to examine the effects of soil physical properties on the growth of yellow birch before pursuing the nutrition studies any farther. The purpose was twofold: first, to better understand the influence of physical properties themselves; and second, to be able to make some allowance for physical effects when evaluating the effects of chemical and micro-organism factors.

Forest soils consist of several distinct layers or horizons that have developed as a result of weathering processes and the influence of vegetation. These horizons are generally recognizable by color differences. Though birch roots are concentrated in the upper horizons, a few roots are found in the lower horizons. Therefore all mineral horizons were considered in this study.

Horizon differences and soil physical properties were tested. Specifically, the objectives were to discover which horizons of a well-drained podzol soil were most favorable to growth of yellow birch and what treatment or combination of treatments to modify bulk density and aeration would permit the best growth in each horizon.

The Soil

The Hermon soil used in the study was collected beneath a northern hardwood stand on the Northeastern Forest Experiment Station's experimental forest at Bartlett, New Hampshire. The Hermon series is a well-drained deep podzol developed on loose late Wisconsin glacial till derived from granite and gneiss. Hermon soils are characteristically stony and are generally found on gently rolling morainic uplands in Maine, New Hampshire, Vermont, western Massachusetts, and northeastern New York.

A description of the study soil is given in table 1. By the American system, this soil would be called a loamy sand; but because it averages about 70 percent sand and 30 percent silt

Table 1. — *A descriptive illustration of the Hermon soil profile used in this study*

Horizon thickness (inches)	Horizon label	Horizon description
½ to 1	L	The litter layer consists of recently deposited leaves, twigs, and bark of birch, beech, and maple.
¼ to ½	F	The fermented layer consists of partially decomposed litter.
1¼ to 1½	H	The humus layer consists of completely decomposed litter and is a black, amorphous material.
1½ to 2	A_2	The A_2 horizon is light to dark gray as a result of severe leaching of soluble salts, iron, aluminum, and clay.
3 to 4	B_{22}	The B_{22} horizon is the zone of maximum accumulation of iron, aluminum, organic matter, and clay removed from the A. Color is dark reddish-brown.
9 to 10	B_{23}	The B_{23} horizon is similar to the B_{22}, but has a lower amount of deposited materials and a yellowish-brown color.
6 to 7	B_3	The B_3 horizon is transitional to the C horizon below and has a light yellow color.
12 +	C	The C horizon is the slightly weathered parent material, from which the overlying A and B horizons probably developed. Color is light olive gray.

Table 2. — *Some physical properties of the Hermon soil horizons*

Horizon	Bulk density	Pore volume	Air volume	Water volume[1]
	g/cc.	*Percent*	*Percent*	*Percent*
H	0.26	95.9	50.7	45.2
A_2	.97	63.4	17.4	46.0
B_{22}	.72	72.8	29.5	43.3
B_{23}	.96	63.7	25.6	38.1
B_3	1.20	54.7	26.4	28.3
C	1.43	46.1	21.1	25.0

[1] At 0.06 atmospheres tension.

with little or no clay content, the Canadian term "silty sand" seems more fitting.

Additional physical properties are shown in table 2. Moisture-holding capacities (last column) are generally good. Wilde (1958) reported that air volumes of forest soils supporting vigorous hardwood stands are seldom below 15 percent. Only the A_2 horizon of the Hermon soil comes close to this minimum value. Pore volumes are generally well above the 40-percent limit reported by Hidding and van den Berg (1961) to obstruct root penetration of field crops. Also, bulk densities are lower than the restrictive value of 1.75 put forth by Veihmeyer and Hendrickson (1948).

Soil chemical analyses[1] indicated that important nutrients were in low supply. Nitrogen and potassium were measured in every horizon, and greatest amounts were found in the H and A_2. Exchangeable calcium was found only in the H and A_2; and exchangeable magnesium only in the H, B_{22}, and B_{23}. Soil acidity ranged from pH 3.8 to 5.3 (H and C horizons respectively).

Procedures

Soil Treatments

Bulk soil samples of six horizons (H, A_2, B_{22}, B_{23}, B_3, and C) were collected separately in sacks and allowed to attain an air-dry condition before storage. In the laboratory, previously weighed

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[1] Hoyle, M. C. VARIATIONS IN FOLIAGE COMPOSITION AND DIAMETER GROWTH OF YELLOW BIRCH WITH SEASON, SOIL, AND TREE SIZE. In press, Soil Sci. Soc. Amer. Proc.

Table 3.—*Estimated average bulk density of potted soils, by horizons and treatments*

Horizon	S[1]	SO	SF	SFO	S2F	S2FO
H	0.22	0.25	0.21	0.22	0.22	0.19
A_2	.73	.78	.48	.54	.35	.33
B_{22}	.82	.77	.49	.50	.36	.34
B_{23}	1.00	1.02	.63	.64	.42	.42
B_3	1.06	1.04	.64	.67	.45	.46
C	1.34	1.36	.78	.85	.64	.53

[1] Key to treatment symbols: S = Soil receiving distilled water. SO = Soil receiving 0.1 percent H_2O_2. SF = Soil and filler, 1:1 ratio, receiving distilled water. SFO = Soil and filler, 1:1 ratio, receiving 0.1 percent H_2O_2. S2F = Soil and filler, 1:2 ratio, receiving distilled water. S2FO = Soil and filler, 1:2 ratio, receiving 0.1 percent H_2O_2.

4.5-inch clay pots were filled with soil material. The pots were reweighed after filling to obtain estimates of soil bulk density. Commercial vermiculite (Terralite) was used as an inert[2] filler material to modify the natural soil bulk density.

Three soil bulk density treatments were developed for each horizon: 500 ml. of air-dry soil (control); 250 ml. soil plus 250 ml. filler (a 1:1 ratio by volume of soil to filler); 167 ml. of soil plus 334 ml. of filler (a 1:2 ratio of soil to filler). The potted soil bulk densities are given in table 3. Generally the 1:1 ratio reduced natural bulk densities by 30 to 40 percent and the 1:2 ratio by 50 to 60 percent. Humus bulk density was not altered by addition of filler. This offered a means of evaluating some extraneous influences of the filler, such as a fertilizer effect and the effect of reducing pot soil volume.

Supplemental oxygen was provided by watering the "0" pots with 0.1 percent hydrogen peroxide (H_2O_2) after the method of Melsted *et al* (1949).

Seeds

Seeds used in this study were all collected from one dominant yellow birch tree on the Bartlett Experimental Forest. Cones were air-dried, broken up, and sieved to separate seed from bracts. Seeds were further separated into two sizes — those that would pass a 10-mesh sieve and those that would not. The larger seeds were sown in several germination trays filled with coarse sand

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[2] Ideally, such filler should be chemically inert, that is, devoid of any plant nutrients. Vermiculite is nearly so, but it does contain small quantities of available bases, mostly potassium.

and vermiculite. Trays were watered daily and kept under cool white fluorescent lights.

After germination, four apparently healthy seedlings were planted in each pot. The first true leaves were just emerging at time of planting. All potted soils were kept at the field-moist condition by frequent watering from below.

Environmental Conditions

A chamber was constructed to provide favorable lighting. Two banks of four F96T12CW Slimline fluorescent lamps (Sylvania)[3] plus three 60-watt incandescent bulbs yielded light intensities of 100 to 2,000 foot-candles according to height of lamps above the pots. Light at about 300 foot-candles at pot level was maintained for the first 5 weeks, and at approximately 1,000 foot-candles for the rest of the experiment. Seedlings were grown under a 21-hour photoperiod composed of fluorescent light from 9 p.m. to 5 p.m. and incandescent light from 4 p.m. to 6 p.m. Day temperatures of 24° C., night temperatures of 21° C., and a relative humidity of 51 percent generally prevailed in the chamber. Pots were rearranged weekly to offset a slight variation in light intensities.

Measurements

Height measurements were taken periodically from the point of cotyledon attachment to the growing tip. At termination of the study, above-ground portions of the seedlings were collected, dried at 70° C., and weighed.

Experimental Design

This study was originally designed as a 6 x 3 x 2 Model I (fixed treatment effects) factorial. Specifically, the factors were: (1) horizons — six levels; (2) bulk density treatments — three levels; (3) oxygen treatments — two levels. Three replications gave a total of 108 pots.

However, because of wide differences in growth rates among horizons, all pots were not terminated at the same time. In addition, many pots yielded seedlings of such small size that meaningful weight data could not be obtained. Consequently, where permissible, these data have been subjected to Tukey's method of testing for significant differences among treatment means (Snedecor 1956). Height data are presented graphically.

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[3] Mention of trade names does not imply endorsement by the U. S. Department of Agriculture.

Results and Discussion

Height Growth

The greatest differences in height growth occurred between horizons. Smaller differences that resulted from soil treatments developed within the top three horizons, but not within the lower three (table 4). Eighty days after planting, control seedlings in humus (H) were about 27 cm. taller than controls in the A horizon, while seedlings in the untreated B and C horizons remained at their initial size (fig. 1). After 122 days, seedlings in the SF and S2F treatments of the B_{22} horizon finally displayed some measurable height growth (table 4 and fig. 1). All other treatments in this horizon and all those in the lower three horizons remained unchanged.

The rates of seedling height growth in humus were rather high. Slower growing seedlings in the SF series averaged about 8.9 mm. per day in humus over a 20-day period of most rapid growth. Control seedlings (S series) attained a higher rate of 12.0 mm. per day in humus for the same period. The tallest single yellow birch seedling measured in humus at 80 days was 62 cm., which represents an average growth rate of nearly 7.8 mm. per day over the entire period. By comparison, A_2 seedlings (S and SF series) averaged only 4.1 mm. per day over their 20-day period of most rapid height growth.

In addition to total size and maximum growth rate obtained, these soil horizons affect yellow birch development by delaying establishment time. For this study, this was defined as the time elapsed between planting and initiation of the period of most rapid height growth. Establishment time for the SF series was

Table 4. — *Average heights (cm.) of yellow birch seedlings at time of last measurement, by horizon and soil treatment*

Horizon	Soil treatment						Days since planting
	S[1]	SO	SF	SFO	S2F	S2FO	
H	42.1	42.4	34.9	34.0	43.7	35.2	80
A_2	25.2	36.4	25.4	28.1	18.0	22.1	117
B_{22}	1.8	1.2	4.6	1.1	4.6	3.0	122
B_{23}	1.3	1.0	1.9	1.2	1.2	1.5	122
B_3	1.5	1.3	1.4	1.5	1.3	1.2	122
C	1.3	1.3	1.8	1.8	1.9	1.6	122

[1] Key to treatment symbols is given in table 3.

approximately 45 days in H, 65 days in A_2, and over 122 days in B_{22}. It was somewhat doubtful if yellow birch in the lower three horizons would ever become established.

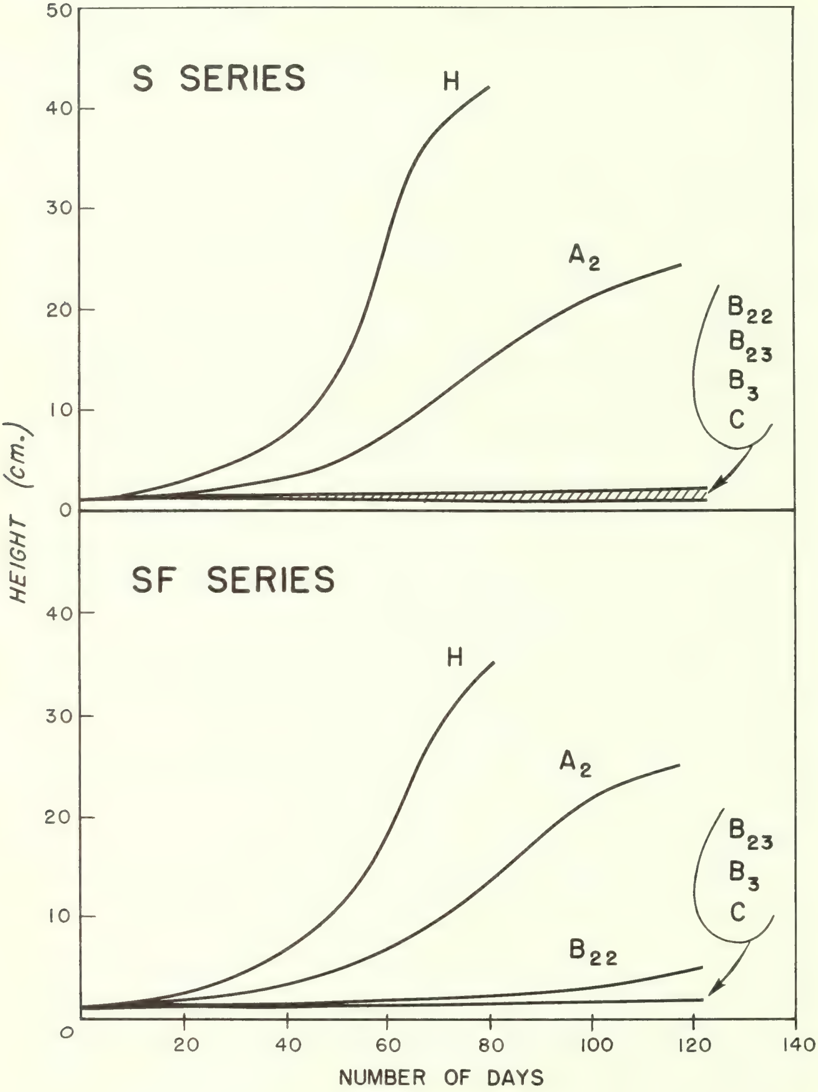

Figure 1. — Height growth curves for yellow birch seedlings growing in the various horizons of a Hermon soil. Top, S series or control; bottom, SF series, a 1:1 ratio of soil to filler by volume.

Dry-Weight Data

Dry weights (by soil treatment) of yellow birch seedlings at time of harvest are given in table 5 for the top three horizons only. After 138 days most seedlings in the subsoil horizons remained alive but had attained little or no additional growth since planting. Consequently, statistical tests for significant differences among treatment means could be determined only for the top three horizons.

Summary statements for the statistical data in table 5 are: (1) For humus, only S2F was significantly greater than S (control series); all other treatments were equal to or less than S. (2) For A_2, only SO was significantly greater than S; all others were not significantly different from S. And (3) for B_{22}, SF and S2F were significantly greater than S; all others were not significantly different from S.

In the absence of any consistent pattern of treatment effects within and among horizons, no acceptable explanation of these results can be offered. However, in view of the height and dry-weight measurements obtained from this study, it was clear that, of the three factors tested, horizons were by far the most influential (fig. 2). Improved seedling growth in the A_2 (resulting from oxygen treatment) and B_{22} (resulting from bulk density treatment) still fell far below that obtained in humus.

Table 5.—*Average dry-weight (mg.) of yellow birch seedlings at time of harvest, by horizon and soil treatment*[1]

Horizon	Soil treatments						Days since planting
	SFO	S2FO	SF	S	SO	S2F	
H	1310	1310	1330	1810	1860	2360	80
	━	━	━				
		━	━				
				━	━		
	S2F	S2FO	SF	S	SFO	SO	
A_2	590	736	875	905	993	1543	117
	━	━	━	━			
		━	━	━	━		
			━	━	━		
				━	━		
	SFO	SO	S	S2FO	SF	S2F	
B_{22}	15	17	30	79	131	134	138
	━	━	━	━			
		━	━	━			
			━	━			
				━	━	━	
					━	━	

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[1] A value is not significantly different (5-percent level) from those to the right of it when connected by a solid line.

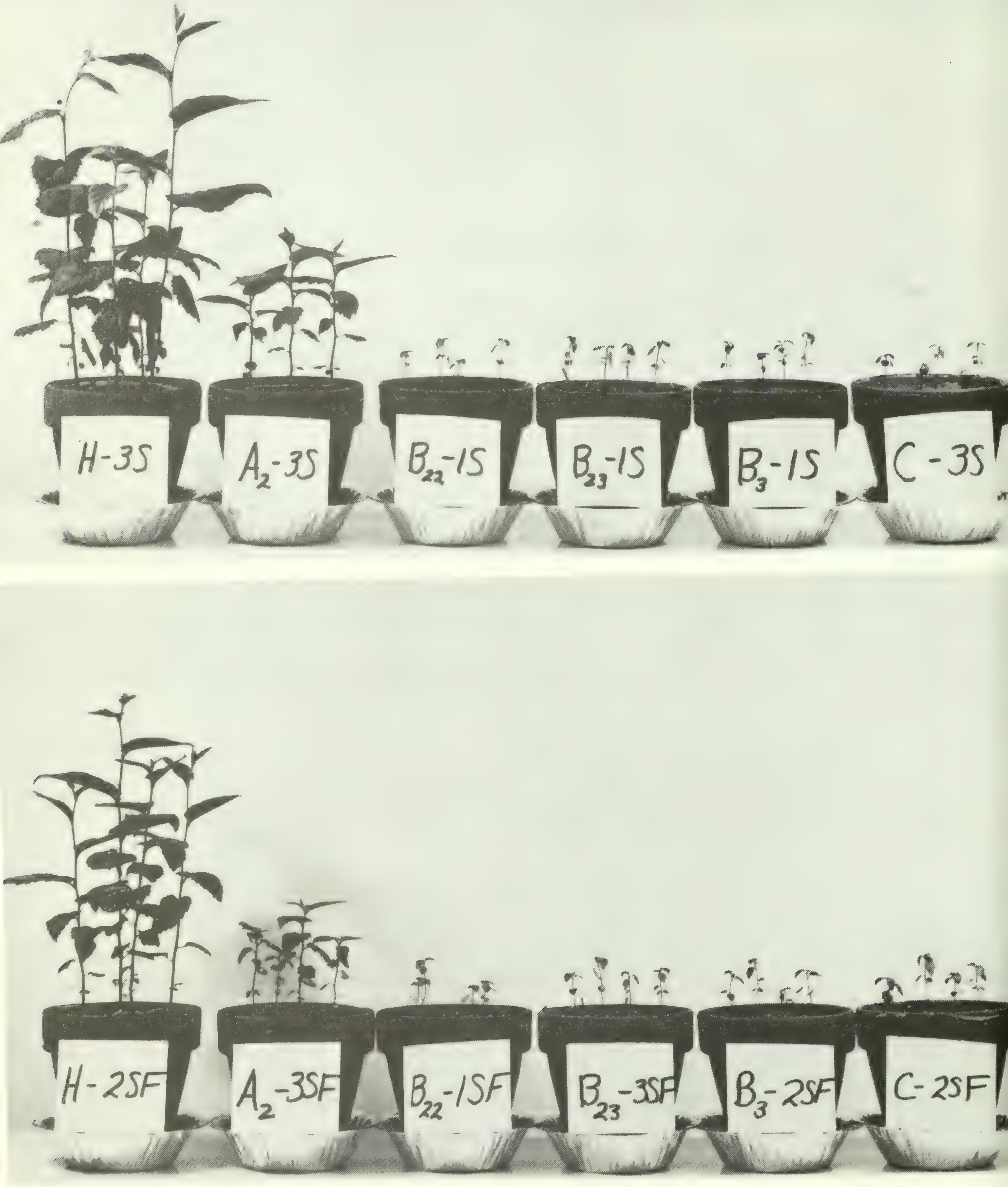

Figure 2. — Comparative growth of yellow birch seedlings at 53 days in the various horizons of a Hermon series, podzol soil. Top, S series or control; bottom, SF series, a 1:1 ratio of soil to filler by volume. (Card numbers refer to replicates.)

With respect to the lower three horizons, where seedlings failed to develop despite adequate light, temperatures, moisture, and treatments to modify soil bulk densities and soil aeration, one may conclude, by elimination, that soil fertility was the primary limiting factor. Certainly, to a lesser degree, this was also indicated for the A_2 and B_{22} horizons.

Seedling Descriptions

As shown, best growth was produced in the humus. Seedlings were large, with deep green leaves and one or several branches (fig. 3). The A_2 seedlings, though of fair size, were stunted by comparison: stems were smaller in diameter and shorter in height; the leaves were much reduced in size and chlorotic; and there was no branch development. Seedlings in the B and C

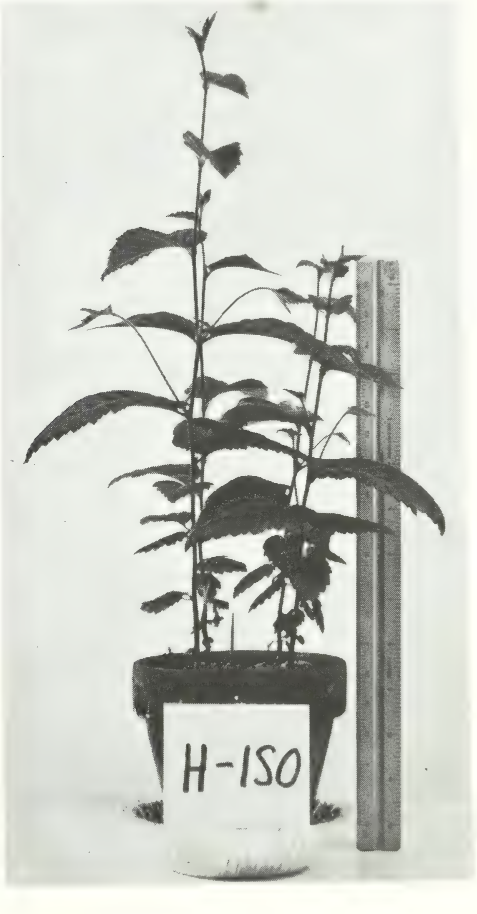

Figure 3. — Yellow birch seedlings growing in humus (SO series, receiving supplemental oxygen). Note the large leaves and good development of branches.

horizons were even poorer: they exhibited only slight development after planting, and several leaves died.

Other than reduction in overall size and general lack of growth, several symptoms appeared on the leaves that further suggested the existence of nutrient deficiencies. Leaves on seedlings in A_2 pots were generally chlorotic. Reddish-purple anthocyanin spots were noted on many leaves. Downward leaf curling was another widespread symptom. Marginal and interveinal necroses were numerous. Humus seedlings, though displaying lush growth, showed three visible leaf symptoms as the plants aged: tip, marginal, and interveinal necroses; slight curling under of the leaf margins; and puckering in the leaves, which produced a blistery surface. Apparently not even the humus provided an optimum nutrient pool for yellow birch development.

Summary and Conclusions

This study was undertaken to determine what soil horizons and treatments to modify bulk density and aeration in each horizon would permit the best growth of yellow birch seedlings. The soil was a podzol belonging to the Hermon series. And the study was conducted indoors to insure adequate light and temperature; sufficient moisture was supplied to the potted soils by frequent waterings. The results of the study are:

- Yellow birch seedling growth was good in humus (H), fair in the A_2 horizon, poor in the B_{22}, and practically nil in the remaining B and C horizons.
- Seedling-height and dry-weight data indicated that treatments to improve bulk density and aeration did not generally produce better growth than the untreated soils.
- The author concluded that soil factors other than moisture, bulk density, and aeration were more severely limiting to growth of yellow birch in the Hermon soil. Soil analyses, plus the size and appearance of birch seedlings, strongly indicated the existence of nutrient deficiencies.

Soil analyses and seedling growth in the various horizons point to humus as the principal source of nutrients in the test soil. Therefore management should certainly provide against excessive loss of humus by wildfire[4] or erosion. In addition, because extensive rooting is very limited in the deeper horizons (for some still unknown reason), root competition in the surface horizons among all types of vegetation present on the site must certainly be severe.

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[4] It is possible that light prescribed burning would provide a temporary fertilizer effect and would be helpful in regenerating yellow birch in clearcut areas.

Consequently, it seems practical to advise the use of early and frequently repeated crop-tree thinnings (Hawley and Smith 1954, pp. 387-388 and 411) in order to reduce root competition between dominant stems. Further reduction in root competition with crop trees by understory trees and woody shrubs could probably be accomplished by mechanical or chemical methods. The purpose of these treatments would be to conserve the small amount of available nutrient capital and to permit use of that capital only by the selected crop trees.

■

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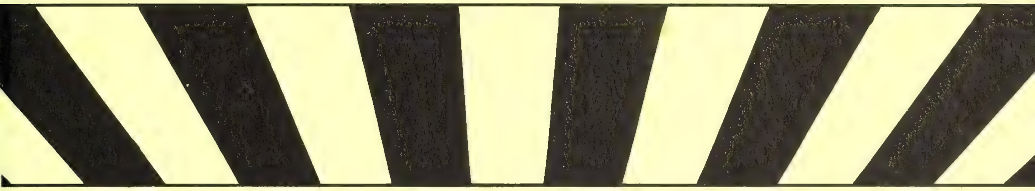
Controlling LIGHT in Small Clearcuttings



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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

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Controlling LIGHT in Small Clearcuttings

■

Importance of Light

THE various methods of regeneration cutting in use today differ from one another primarily in their effect on light exposure. For example, clearcutting permits a maximum of sunlight to reach the ground, while light selection cutting admits very little sunlight beneath the residual canopy. Small clearcuttings,[1] although seldom used, offer exceptionally good opportunities for the control of light exposure. The size, shape, and orientation of these openings can be varied to obtain light conditions ranging from full sunlight to no direct sunlight at all; from exposure during only the middle hours of the day to exposure only early in the morning or late in the afternoon. A better knowledge of the light obtained in these small clearcuttings is essential if they are to be used effectively for obtaining desired types of regeneration.

The amount of light that reaches the ground in a clearcut forest area is one of the basic environmental factors. It affects tree and shrub growth, transpiration, evaporation, soil moisture, snow melt and accumulation, frost occurrence, soil and air temperature, decomposition of organic matter, and other factors.

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[1] Small clearcuttings in the present context mean areas of 1 acre or less, or strips no wider than the height of the bordering timber, on which all trees have been cut.

Control of light to create particular environments could be one of our most valuable management tools. The silviculturist could favor or discriminate against a particular species by using an appropriate cutting method. The wildlife manager could increase game populations by favoring certain food and cover plants. The watershed manager might alter streamflow patterns by cuttings designed to affect snow accumulation, snow melt, and other moisture relationships.

Small clearcuttings have already been used occasionally to meet these objectives. But all too often the cuttings are made without full realization of how the physical dimensions of the opening affect the primary environmental factor that is being manipulated — the sunlight reaching the forest floor.

In the Northeast, we are attempting to regenerate paper birch and yellow birch by cuttings designed to provide optimum environmental conditions for these species. Early studies have shown that small clearcuttings favor establishment of the birches, and that the size of the opening affects the amount and composition of the reproduction. But what type and size of opening will provide the best conditions? To answer this, we need to know what environmental conditions are best; and we need to know how the method of cutting affects those conditions.

Some pertinent information is available. Seeds of both species require abundant moisture for germination, and new seedlings require freely available moisture and moderate soil temperatures to survive. These conditions commonly prevail in the shaded borders of small clearcuttings. However, *some* direct sunlight is needed for growth. The two species differ somewhat in the amount of sunlight they need: paper birch apparently requires more light for growth, and withstands the dessicating effects of direct sunlight better than yellow birch. Thus each species regenerates best under a particular combination of sun and shade that is, in effect, a compromise: enough shade to permit germination and initial establishment, and enough sun to promote reasonably good growth.

More information is needed. Among other things, we need to know precisely what the light conditions are in the various types of openings. In 1960, a study was made of the patterns of sunlight and shade in small clearcuttings. This report illustrates some of the patterns and suggests how such cuttings might be done for regeneration purposes.

Procedures

The pattern of sunlight and shade created by border trees was sketched for various types of openings at different hours of the day. This required computation, for the different hours, of these three determinants:

(1) Sun's angle of elevation (altitude).

(2) Shadow length of border trees.

(3) Sun's bearing (horizontal angle between sun and due south).

The three determinants were computed by the following formulae, respectively:

[1] Sine a = (cosine L) (cosine d) (cosine H) + (sine L) (sine d).

[2] S = h/tangent a.

[3] Tangent Z = sine H/(cosine L) (cotangent p) — (sine L)(cosine H).

where:

a = sun's angle of elevation
L = latitude
d = sun's declination as obtained from a solar ephemeris.[2]
H = sun's hour angle (15 times the number of hours from solar noon).
S = shadow length cast by border trees.
h = height of border trees.
Z = sun's bearing.
p = polar angle (90° — sun's declination).

Table 1 shows computed sun positions for the hours 8 a.m. to 4 p.m. as of June 7 at latitude N. 44°, and shadow lengths for border trees 70 feet tall on level ground. The values would be different for different dates, latitudes, tree heights, or topography.

The values in table 1 are presented as examples to illustrate how shadow lengths change with sun position, and as a basis for sketches of sun-shade patterns. June 7 was chosen because it represents the median condition for the 2-month period May 21

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[2] A solar ephemeris is a booklet of tables showing the calculated positions and motions of the sun from day to day. They are published by various government agencies and private companies.

TABLE 1. Sun's apparent position at hourly intervals on June 7 from latitude N. 44°, and shadows cast by 70-foot trees

Hour, true solar time	Sun's hour angle	Sun's bearing	Sun's angle of elevation	Length of shadow cast by 70-foot tree on level ground, feet
8:00	60°	S 87° E	36°55′	93
9:00	45°	S 75° E	47°34′	64
10:00	30°	S 59° E	57°30′	45
11:00	15°	S 35° E	65°28′	32
12:00	0°	South	68°48′	27
1:00	15°	S 35° W	65°28′	32
2:00	30°	S 59° W	57°31′	45
3:00	45°	S 75° W	47°34′	64
4:00	60°	S 87° W	36°56′	93

to July 21[3], which is generally the most critical period for germination and initial seedling establishment. The hours shown are true solar time. The middle 8 hours of the day, from 8 a.m. to 4 p.m., are regarded as the critical part of the day for young seedlings, even though in certain orientations of stand openings, some direct sunlight may be received at earlier or later hours. In the discussion to follow, the term *day* generally refers to the period 8 a.m. to 4 p.m.

Results

The shade with which we are concerned is the open shade cast by trees along the borders of small clearcuttings (fig. 1). This area of open shade occurs because, in the temperate zone, the sun never gets directly overhead. Thus one or another of the borders will cast a shadow onto the clearcut area at any given time of day. Because the sun's apparent position changes, this area of shade also changes during the day.

From our position on earth, the sun appears to move from a low angle in the east in the morning to a high angle in the south at noon, to a low angle in the west in the afternoon. As a result,

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[3] During this 2-month period there is comparatively little variation in the sun's angle—a total of 3¼° versus a variation of about 47° over the year. During this period, shadows will be slightly shorter on half the days, slightly longer the other half. The difference in noon-time shadow-lengths between June 7 and June 21 is 3 feet.

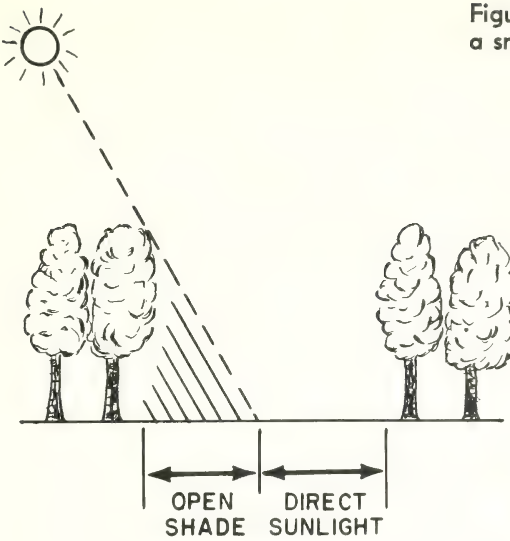

Figure 1.—Open shade in a small clearcutting.

any clearcutting will have shaded areas along its east border in the morning, its west border in the afternoon, and its south border during both morning and afternoon (fig. 2). The shaded area in any clearcutting follows the general pattern shown in figure 2; but the size, shape, and orientation of the opening affect the pattern considerably.

Small clearcuttings may be grouped into two categories: (1) patches — round, square, rectangular, or irregular openings for which the dimensions are either equal or not greatly different;

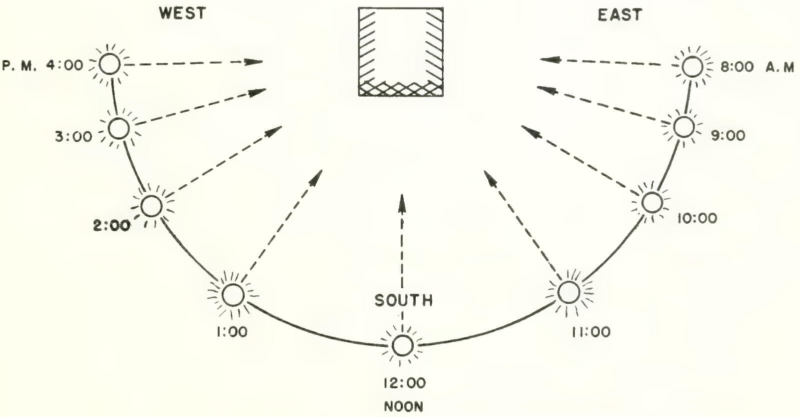

Figure 2.—Apparent movement of the sun around a small clearcutting.

and (2) strips — long, narrow openings in which the length is many times the width. In strip cuttings, the shade cast by border trees on the short sides (ends) is so small, relatively, that it may be ignored. In patch cuttings, however, the shade from east, south, and west borders must all be considered.

In patches, size affects the amount of sunlight reaching the ground more than either shape or orientation. The larger the patch, the greater the proportion of it that will receive direct sunlight. Shape and orientation are most important where the size of patch is about ½ acre. For very small (1/10 acre) or very large (1 acre) patches, shape and orientation do not make much difference. For a given size, patches shaped and oriented so as to have the east-west dimension smaller than the north-south dimension will receive less sunlight than others.

Figures 3 and 4 illustrate various patch cuttings. Those in figure 3 are 1/10 acre; those in figure 4 are the same shapes and orientations as those in figure 3, but are ½ acre in size. The numbers at the bottom of each figure represent the average proportion of the patch exposed to direct sunlight over the 8-hour day and may be used for comparisons between the different types. All these diagrams and others in later figures are based on a tree height of 70 feet and level topography.

The changing pattern of sunlight in a patch cutting is further illustrated in figure 5. Here a ½-acre rectangular patch, oriented east-west, has been divided into segments showing the number of hours of sunlight received at various positions. Note that, even in this small opening, part of the area gets full sunlight during the 8-hour day, and that exposures range all the way from full sunlight to full shade.

In strip cuttings, both orientation and width affect the amount and pattern of sunlight; orientation is especially important when strips are relatively narrow. An east-west orientation best utilizes the shade of the south border. When so oriented, narrow strips receive sunlight early in the morning and late in the afternoon, but are shaded in large part during the middle of the day. Width of strip is critical. To be completely shaded all day, the strip could be no more than 5 feet wide. However, a strip 23 feet wide would receive no sunlight between 10 a.m. and 2 p.m. (fig. 6). In wider east-west strips, all area beyond 27 feet from the south edge, except near the ends, would receive full sunlight.

North-south oriented strips have an opposite pattern. They are most exposed around noon, when the sun shines directly down the long axis; and are more shaded in the morning and afternoon.

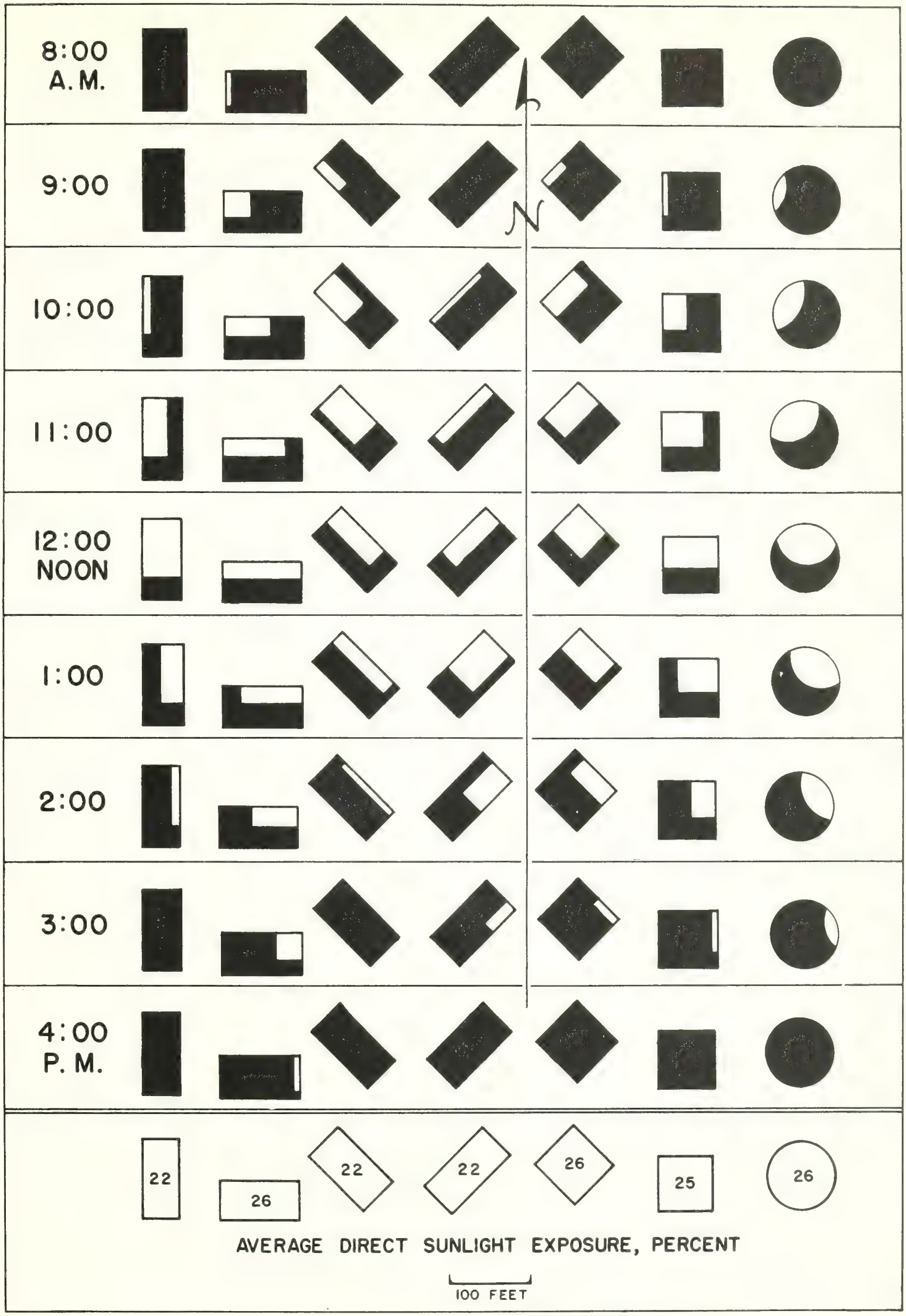

Figure 3.—Patterns of light and shade in various 1/10-acre patches—June 7, latitude N. 44°, at different times of day.

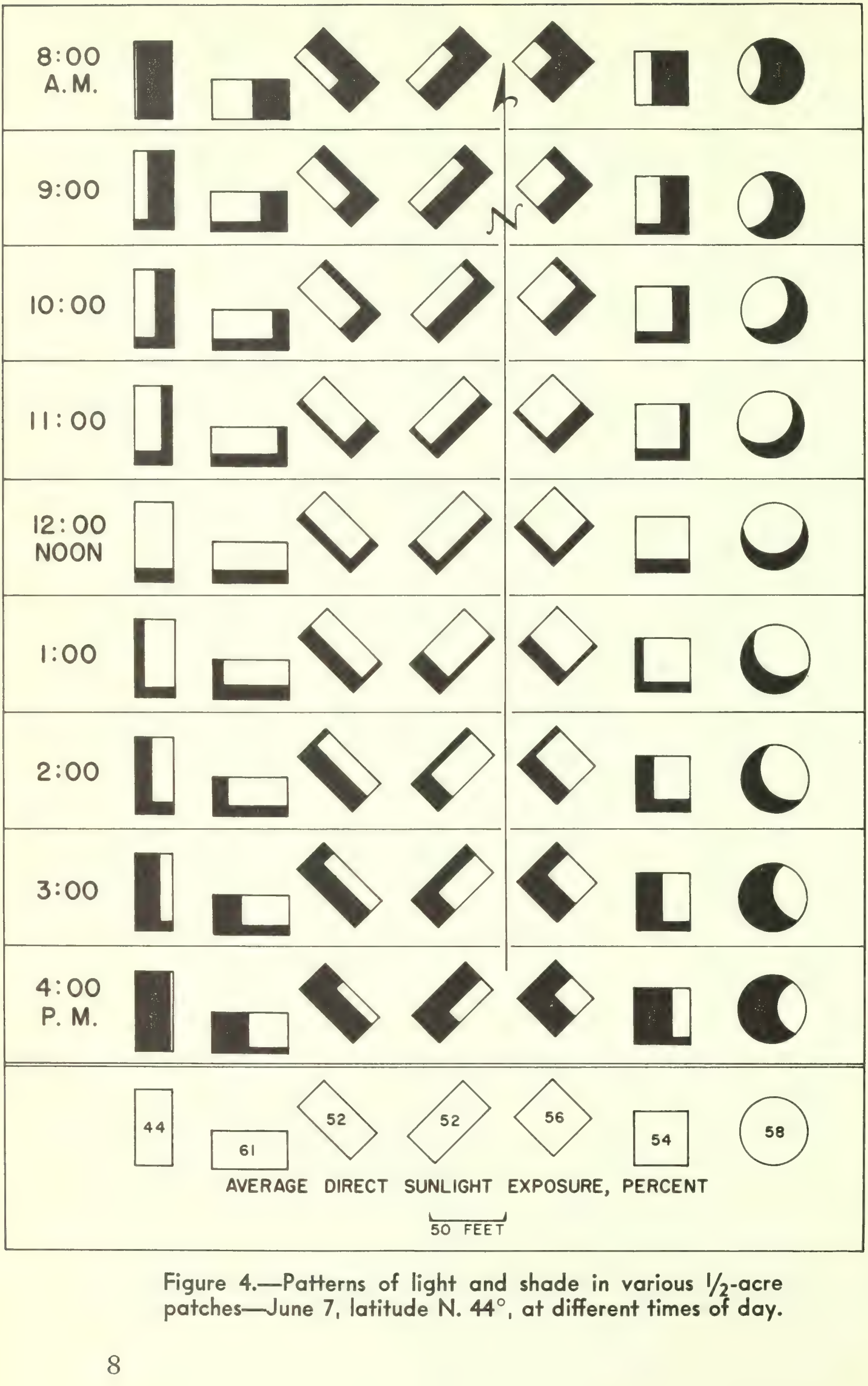

Figure 4.—Patterns of light and shade in various ½-acre patches—June 7, latitude N. 44°, at different times of day.

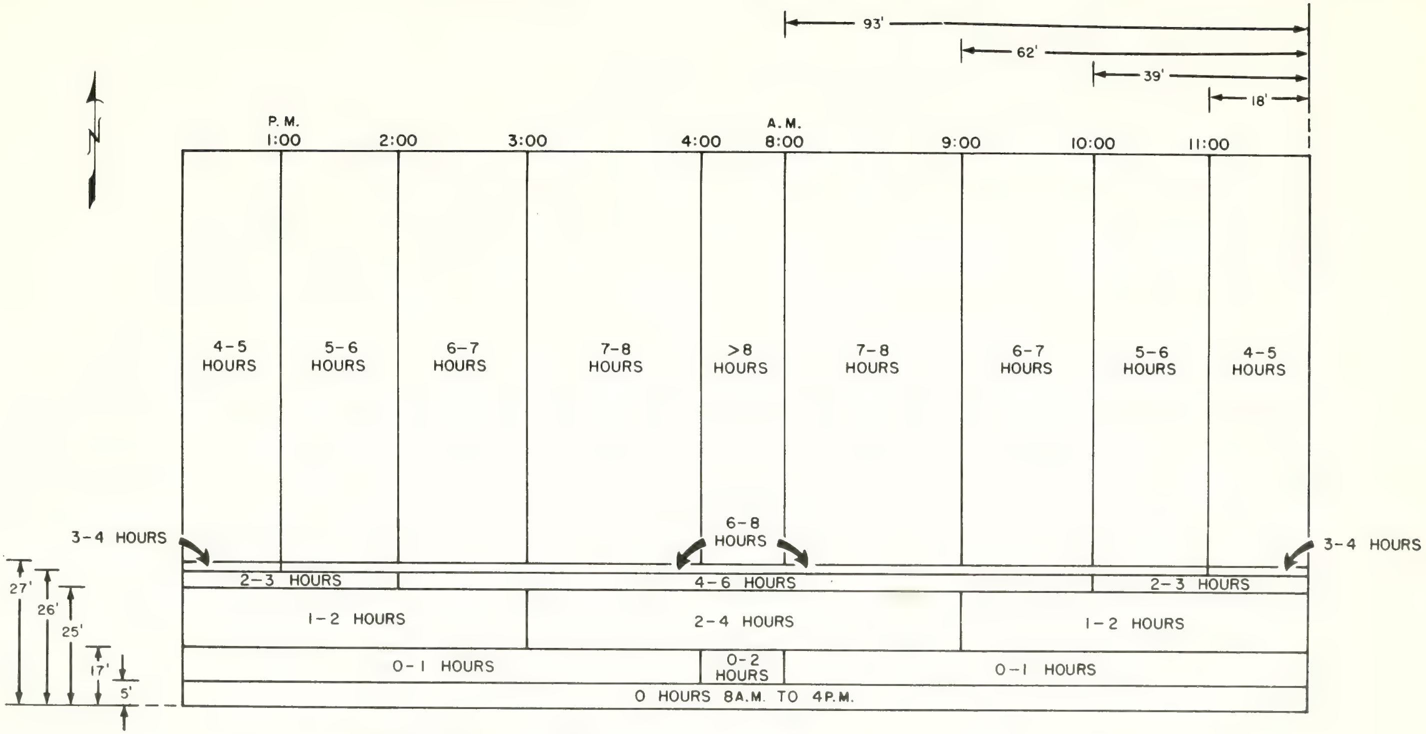

Figure 5.—Length of exposure to sunlight at various positions in a 100-foot x 200-foot (1/2-acre) opening, 8:00 a.m. to 4:00 p.m.

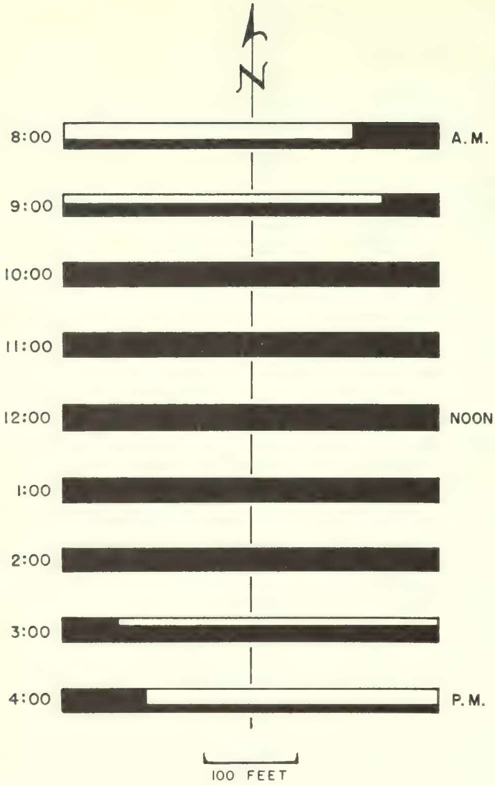

Figure 6. — Patterns of light and shade in an east-west strip 23 feet wide — June 7, latitude N. 44°.

The width of a north-south strip determines how long before and after noon it will receive sunlight. A strip 70 feet wide receives about 3½ hours' exposure; a strip 50 feet wide receives about 2½ hours' exposure; and a strip 35 feet wide receives about 2 hours' exposure. All locations within a north-south strip, except the 27-foot strip along the south edge, receive about the same amount of sunlight. Figure 7 illustrates the patterns in a north-south strip 50 feet wide.

Strip cuttings oriented at other than the cardinal directions have still different patterns. A northeast-southwest strip would be most exposed around 1:30 in the afternoon when the sun shines directly down its long axis. In the morning, the sun would be perpendicular to the long axis and much of the strip would be shaded. Conversely, a northwest-southeast strip would be most exposed in the morning and most shaded in the afternoon. Width again determines how long a strip will be exposed. A strip 30 feet wide receives about 1¾ hours and one 40 feet wide receives about 2½ hours of direct sunlight.

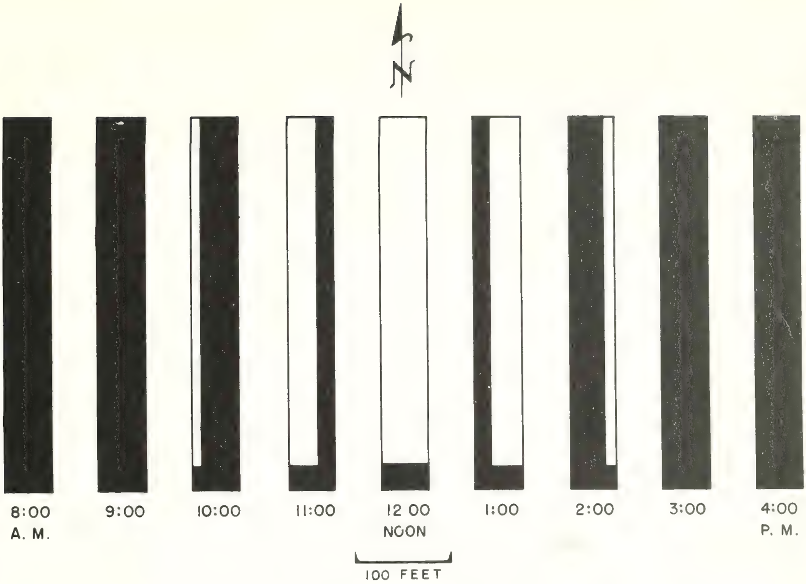

Figure 7.—Patterns of light and shade in a north-south strip 50 feet wide—June 7, latitude N. 44°.

Figure 8 illustrates the patterns in a northwest-southeast strip 30 feet wide. Such a strip offers interesting conditions: It receives sunlight needed for seedling growth during the cool morning hours and is shaded during the hot afternoon hours when direct sunlight is most likely to cause unfavorable conditions of heating and drying.

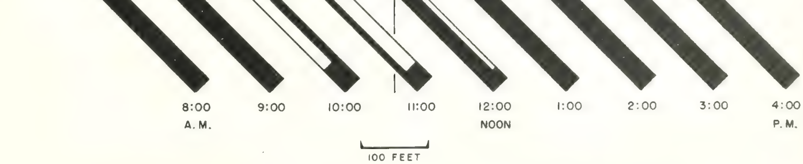

Figure 8.—Patterns of light and shade in a northwest-southeast strip 30 feet wide—June 7, latitude N. 44°.

Discussion

The selection of a type of cutting for regenerating any species must be based on a thorough knowledge of the environmental requirements of the species and on the environment created by different amounts of light and shade. As previously mentioned, the environmental requirements of the birches differ at various stages of development. During germination and early establishment, shade is desirable to conserve soil moisture and maintain moderate soil temperatures. Once established, however, the seedlings require considerable sunlight for best growth.

If cutting is done in a manner to provide shade for seedling establishment, provision must be made to release the seedlings from this shade after a few years. This can be done by locating the next cuttings in the series adjacent to the previous ones. Then, however, light patterns must be considered not only for single cuttings, but also for the combined openings of adjacent cuttings. Hence the entire series of cuttings must be planned in advance.

The strip system lends itself well to cuttings in a planned series. Many arrangements of strips and sequences of cutting are possible.

One example of such a series is illustrated in figure 9, A. Here the strips run east and west. Strip 1, at the northern edge of the area, is cut first. After cutting, it receives shade from the trees on its south border. This provides good conditions for germination and early survival. After an establishment period of several years, strip 2 is cut. Strip 2 then receives shade for initial establishment while strip 1 receives direct sunlight most of the day. After another period of several years, strip 3 is cut, then strip 4, and so on until the entire tract has been covered. Thus each strip first receives shade for seedling establishment and then direct sunlight for best growth.

The interval between cuttings would probably be 2 or 3 years, but it could be flexible in accordance with seed crops. In most cases, we would divide the area into sections of 2 to 4 strips each and cut simultaneously in each section. This would permit the entire cutting operation to take place within a short period of time — 6 to 9 years or less — thus establishing a relatively even-aged new stand that could be managed as a unit.

A similar series of strips could be laid out with a northwest-southeast orientation (fig. 9, B). Cutting would progress from northeast to southwest. This orientation would provide some additional sunlight in the morning, as compared to east-west strips. On strips 30 feet wide, all of the area would get some morning sunlight, but would be completely shaded all afternoon (fig. 8).

North-south oriented strips depend equally on east and west borders for shade, and therefore do not lend themselves well to serial cuttings. Only the first strip cut through a stand or section of a stand is adequately shaded; cutting a second strip on either side then reduces the shade so much that most of the advantage of the strip system is lost. About the best arrangement possible with north-south strips is the simple 1-2 alternate layout shown in figure 9, C. All the number 1 strips, comprising half the stand area, would be adequately shaded for seedling establishment. But the number 2 strips, when cut, would be left completely exposed.

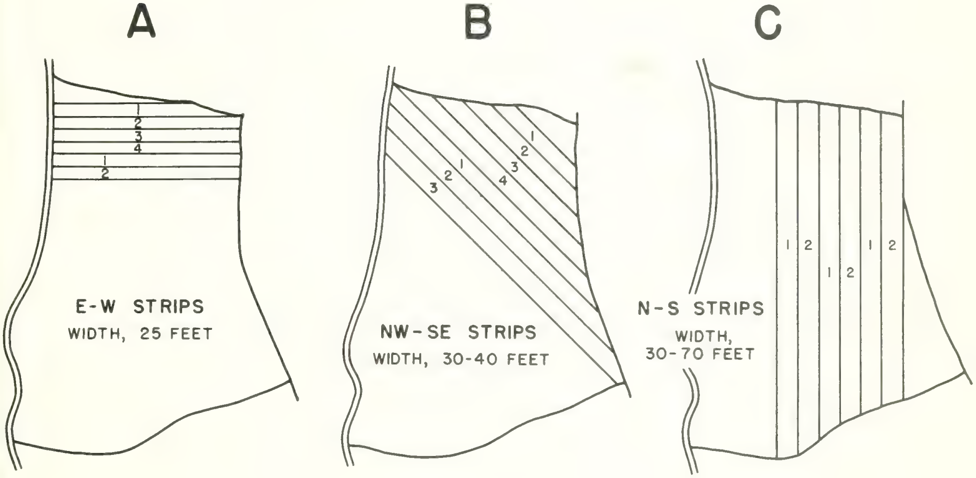

Figure 9.—Three possible layouts of strip cuttings in a management area. (Not to scale.)

Actually, the last strip in any series, regardless of orientation, is left exposed. But with orientations other than north-south, series consisting of more than two strips are feasible and a larger proportion of the total area gets shaded through one cutting cycle. Nevertheless, despite their shortcomings, north-south series of strips may be useful in some situations.

Another possibility with north-south strips would be to schedule the cuts on the number 1 and number 2 strips a half rotation apart. Thus the young trees on each strip 1 would reach almost full height before the number 2 strips were cut, and all strips would be shaded from both sides during the crucial period of seedling establishment. If the strips were wide (50 feet to 70 feet), the long-continued partial shade might not reduce height growth too seriously. The biggest disadvantage would be the long exposure of uncut strips to windthrow and other damage.

The strip widths shown in figure 9 are those that most fully utilize the available shade from each orientation. Some of the specified widths are relatively narrow, and it is questionable whether such narrow strips are practical to cut. Substitution of wider strips should be done cautiously, though, because small changes in width can result in surprisingly large changes in light exposure. For example, increasing the width of a north-south strip from 50 feet to 100 feet would increase the length of time that the strip is exposed to direct sunlight from 2½ to 5 hours. All areas in the strip would be equally affected. Such an increase in light exposure would be acceptable only if the desired species would regenerate satisfactorily under these conditions.

Increasing the width of an east-west strip has a different effect. As previously explained, a 23-foot wide east-west strip would be shaded throughout the middle of the day. Increasing the width would not affect the shade within 23 feet of the south edge, but all areas beyond 27 feet would receive full sunlight. Such a cutting might be acceptable, or even desirable, if it would result in a mixture of several valuable species. Such a mixture might be expected in northern hardwoods where yellow birch commonly regenerates in the more shaded portions, and paper birch in the sunnier portions, of small clearcuttings.

Sketches of any contemplated cutting will quickly reveal whether or not the desired light exposure will be obtained. Such sketches can readily be made by use of data from table 1 and figure 5. Strictly speaking, these data apply only for June 7, at latitude N. 44°, in stands 70 feet tall, and on level ground. For practical purposes, however, small departures from these conditions can be ignored. For situations that are substantially different, shadow lengths may be computed by the procedures outlined earlier in this paper. These computations are relatively simple and can be made quickly.[4] Where a lower degree of accuracy is acceptable, approximate shadow lengths for different situations can be determined by adjusting any available computed values according to the following guides.

Latitude.—Noon-time shadow length decreases about 3 feet for every 2 degrees southward in latitude. Morning (8 a.m.) and afternoon (4 p.m.) shadow lengths are not much affected by latitude within the United States and adjacent Canada. Thus, shade from an east-west border would not be of much silvicultural significance in the southern United States, but shade from north-south borders would still be useful.

Tree height.—Noon-time shadow length increases about 2 feet for every 5-foot increase in tree height. Morning and afternoon shadow lengths increase about 7 feet for each 5-foot increase in tree height.

Slope.—Noon-time shadow lengths increase about 1½ feet for each 10 percent increase in slope on north aspects and decrease similarly on south aspects. Thus, an east-west strip should be wider on a north slope and narrower on a south slope than on level ground. Even on a 40-percent slope, the strip width would be altered by only 5 to 6 feet. Adjustments would not be worthwhile on east or west slopes.

The change in morning and afternoon shadow lengths on east and west aspects varies from 15 feet on a 10-percent slope to 46 feet on a 40-percent slope. On a north-south strip, shadow lengths would not be much affected by north or south slopes, but would be altered on east or west slopes. However, adjustments in strip width are not called for, even in the latter situations, because changes in shadow length from one border on an east or west slope would be compensated by an equal and opposite change in shadow length from the other border. The net result would be a slight shift in the time of day when the strip is exposed to direct sunlight, but little change in the length of this exposure.

Although similar patterns of sunlight and shade can be obtained on both level and sloping ground, the insolation received per unit of ground area in direct sunlight differs with slope and aspect. An exposed area on a south slope receives more energy per unit area in a given interval of time than one in a similar position on a north slope because the light strikes the south slope at an angle closer to the perpendicular. This suggests that, to obtain similar environ-

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[4] Helpful data for computing shadow lengths under different conditions may be obtained from the following sources:

Fons, W. L., H. D. Bruce, and Alan McMasters. Tables for estimating direct beam solar irradiation on slopes at 30° to 46° latitude. U.S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta., 298 pp., 1960.

Aeronautical Services, Inc. Sun angle calculator. Available from Libbey-Owens-Ford Glass Co., Toledo, Ohio. 1951.

Coordinate transformers. Available from G. Felsenthal and Sons, Chicago, Ill.

ments on different slopes and aspects, different lengths of exposure to direct sunlight would be required.

Patch cuttings are not so well adapted for use over large areas as strip cuttings. The problem of fitting new patches in among several series of older ones is difficult to solve. Patch cuttings could probably be best used to advantage if no attempt were made to cover the entire area with patches. Instead, groups of mature, overmature, or defective trees would be used as nuclei for patches to be cut in conjunction with regular selection cuttings. This would help to maintain the less tolerant species such as paper birch and yellow birch in the mixture of tolerants normally maintained under the selection system.

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THE Mensurational Characteristics OF Eastern White Pine

by Robert Marty

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THE Mensurational Characteristics OF Eastern White Pine

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Introduction

THERE probably is a more extensive professional and scientific literature relating to eastern white pine *(Pinus strobus* L.) than for any other North American forest tree species. Unfortunately this material is scattered in thousands of books, theses, bulletins, and journal articles, making access and retrieval a serious problem for the forest researcher and practitioner alike.

Three of the most frequently used classes of white pine mensurational data are estimators of site index, tree volume tables, and stand growth and yield predictors. This paper brings together some of this information. Only the more widely applicable studies are reproduced here; much additional information of local significance is represented in the literature and is available.

This paper is divided into three major sections: *SITE INDEX ESTIMATORS, TREE VOLUME ESTIMATORS,* and *STAND GROWTH AND YIELD ESTIMATORS.* Each section begins with a brief description of the data it contains, but is made up primarily of a set of tables and graphs numbered consecutively within the section. For example, the graph labeled SITE INDEX — 3 is the third table or graph in that section. Table headings have been designed so that most of the information necessary to determine the content of a table, and to distinguish it from others, is condensed in the heading and can be identified quickly.

Site Index Estimators

Site quality is one of the most important determinants of growth and yield. Separate yield tables are prepared for sites of different quality; and site quality is almost always used, directly or indirectly, as a determining variable in other growth and yield predictors as well. The quality of a forest site perhaps is best defined in terms of its potential for producing some product, in this case white pine timber. But site quality has seldom been measured directly in this fashion by foresters, say in terms of maximum sustainable mean annual cubic-foot increment per acre. Instead, site quality has ordinarily been defined in terms of a site index — the height attained by dominant trees at some standard index age.

There are three principal ways of estimating white pine site index. The most common method — and perhaps the most reliable — is to measure the age and total height of pine trees near index age, and determine site index by reference to a set of site-index curves. Site-index curves are constructed to show the relationship of total tree height to age for dominant and codominant trees, which allows estimation of what the height of sample trees was, or will be, at index age.

A second method of estimating site index is on the basis of soil characteristics.[1] Soil characteristics are major determinants of site quality, and they are often correlated rather strongly with other determinants reflecting climate and biotic environment. Moisture availability seems to be a key soil characteristic influencing white pine site quality, at least in some parts of its range.

A third prediction technique makes use of indicator plants. Early work concentrated on relating herbaceous vegetation types with pine site quality. More recently interest has shifted toward relating the site indices of other tree species to pine. These indirect methods, though not so reliable as site-index curves, are essential for situations where suitable pines near index age are not available.

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[1] An allied method relates site index to soil series as defined by the soil-classification procedures used by the Soil Conservation Service of the U. S. Department of Agriculture. Site index-soil series relations sometimes are published by SCS as a part of their soil survey county report series.

In establishing site index from curves, first measure the total height and age at d.b.h. of five or more dominant and codominant pine trees distributed over the stand area. These index trees should show no evidence of past suppression or serious injury and they should not be open-grown trees. Compute the average total height and age at d.b.h., and determine site index from an appropriate set of curves. If the curves you are using are based on age from seed rather than age above d.b.h., the site-index estimate derived above must be corrected. The listing below shows age corrections to add to average age above d.b.h. to convert this measure to average age from seed for Southern Appalachian conditions. Pine trees in New York and New England may take 1 or 2 more years to reach 4½ feet, particularly on the poorer sites.

Preliminary site index estimate based on average age above d. b. h.	*Years to add to age above d. b. h. to convert it to age from seed for Southern Appalachian conditions*[2]
96 or more	4
81-95	5
66-80	6
65 or less	7

The soil-site index estimators should be used in a similar fashion. Take soil observations at five or more locations within the stand, and average the values for factors measured. Then use these average values to derive an estimate of site index from the appropriate table or formula. When estimating white pine site index on the basis of site index for another species, estimate site index for the indicator species in the fashion outlined above for white pine. Then use this average site index for the indicator species to derive an estimate of white pine site index. Frequently more than one of these methods can be employed. Try several methods and see how they compare. This will give you a better basis for interpreting soil and indicator-plant estimates when these are the only recourse.

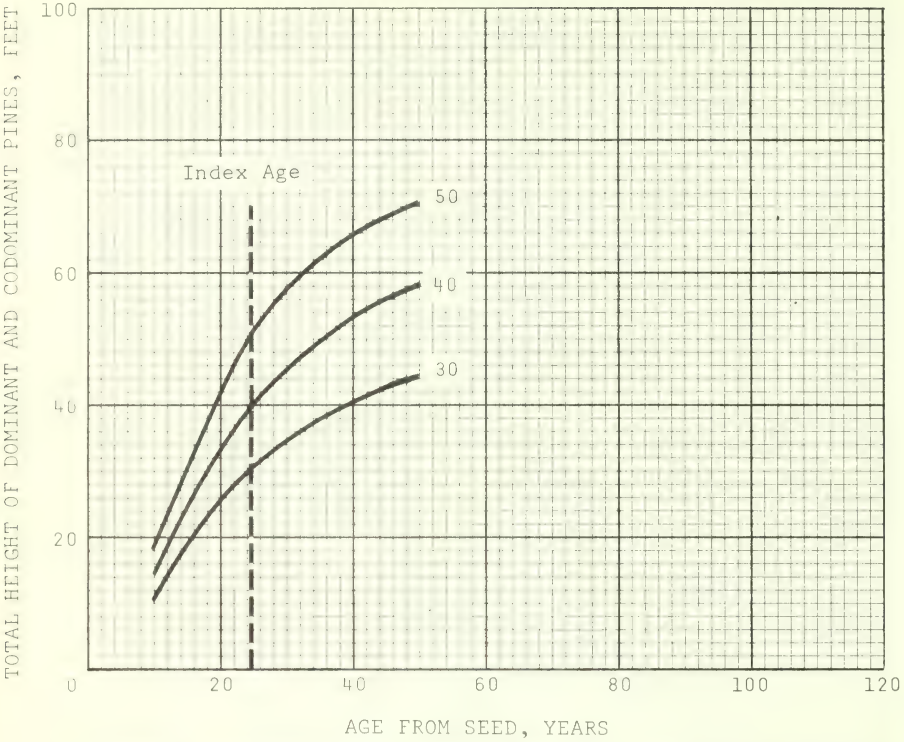
---

[2] Doolittle, W. T., and J. P. Vimmerstedt. SITE INDEX CURVES FOR NATURAL STANDS OF WHITE PINE IN THE SOUTHERN APPALACHIANS. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 141. 2 pp., illus., 1960.

SITE INDEX—1

HEIGHT/AGE CURVES

Pure Plantations—Ohio and Indiana



SOURCE: Gaiser, Richard N., and Robert W. Merz. GROWTH OF PLANTED RED AND WHITE PINE IN OHIO AND INDIANA. U. S. Forest Serv. Central States Forest Expt. Sta. Tech. Paper 134. 14 pp., illus., 1953.

LOCATION: Muskingum, Wellston, Zanesville soil association in parts of Ohio and Indiana.

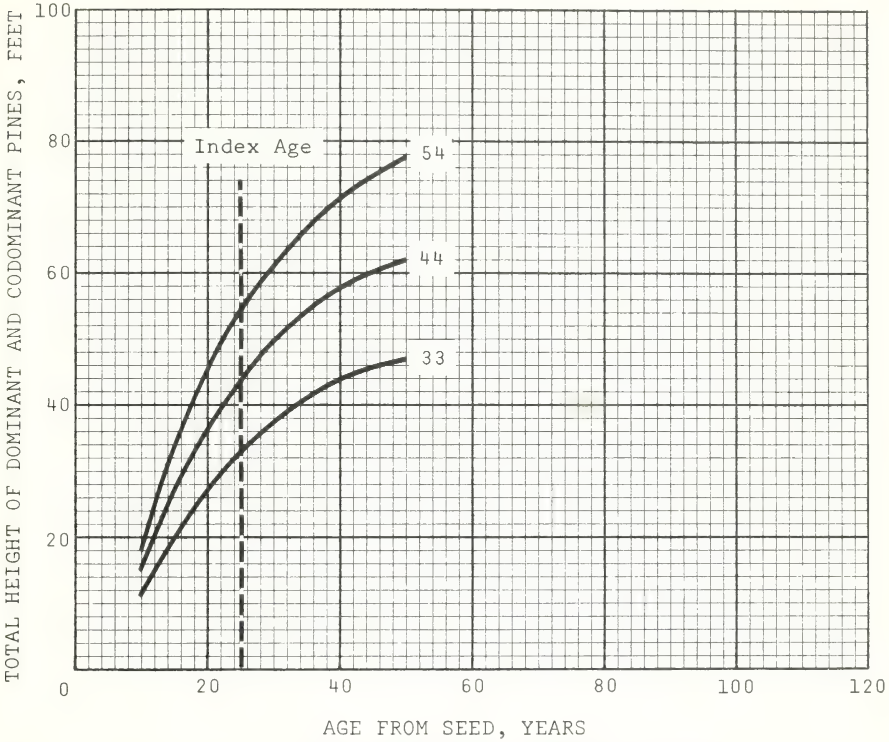
BASIS: Individual tree measurements from 11 plantations.

RELIABILITY: No estimate.

SITE INDEX—2

HEIGHT/AGE CURVES

Mixed Plantations—Ohio and Indiana



SOURCE: Gaiser, Richard N., and Robert W. Merz. GROWTH OF PLANTED RED AND WHITE PINE IN OHIO AND INDIANA. U. S. Forest Serv. Central States Forest Expt. Sta. Tech. Paper 134. 14 pp., illus., 1953.

LOCATION: Muskingum, Wellston, Zanesville soil association in parts of Ohio and Indiana.

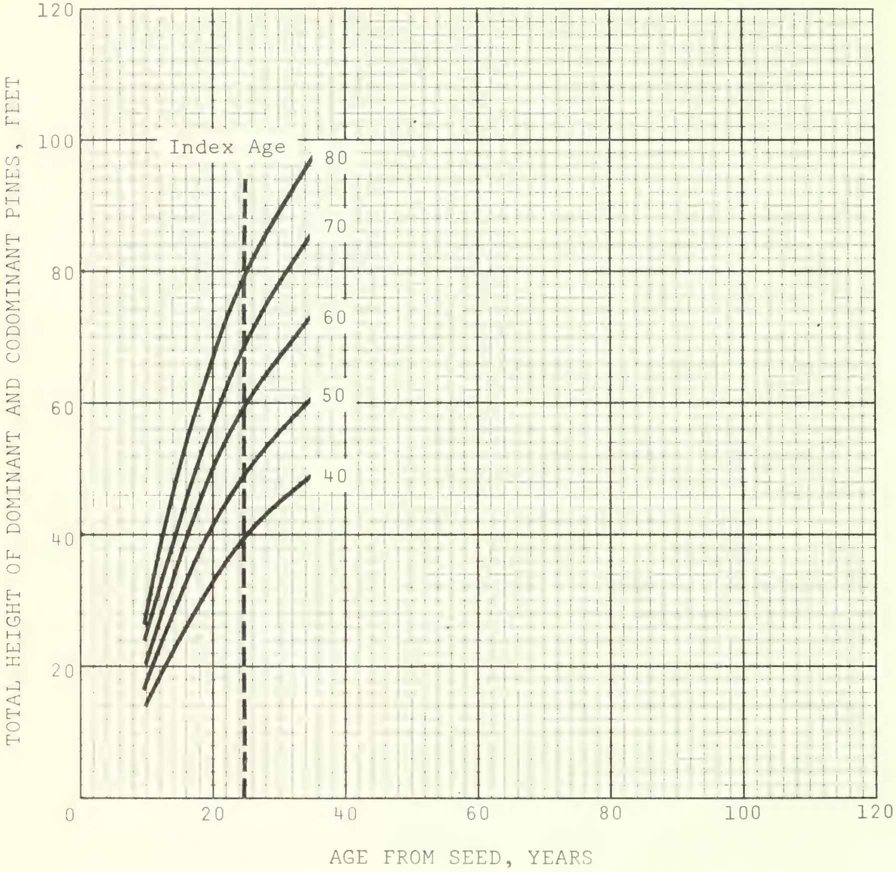
BASIS: Individual tree measurements from 31 plantations.

RELIABILITY: No estimate.

SITE INDEX—3

HEIGHT/AGE CURVES

Pure Plantations—Southern Appalachians



SOURCE: Vimmerstedt, John P. SITE INDEX CURVES FOR SOUTHERN APPALACHIAN WHITE PINE PLANTATIONS. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 131. 2 pp., illus., 1959.

LOCATION: Mostly western North Carolina with some plots in northern Georgia and eastern Tennessee.

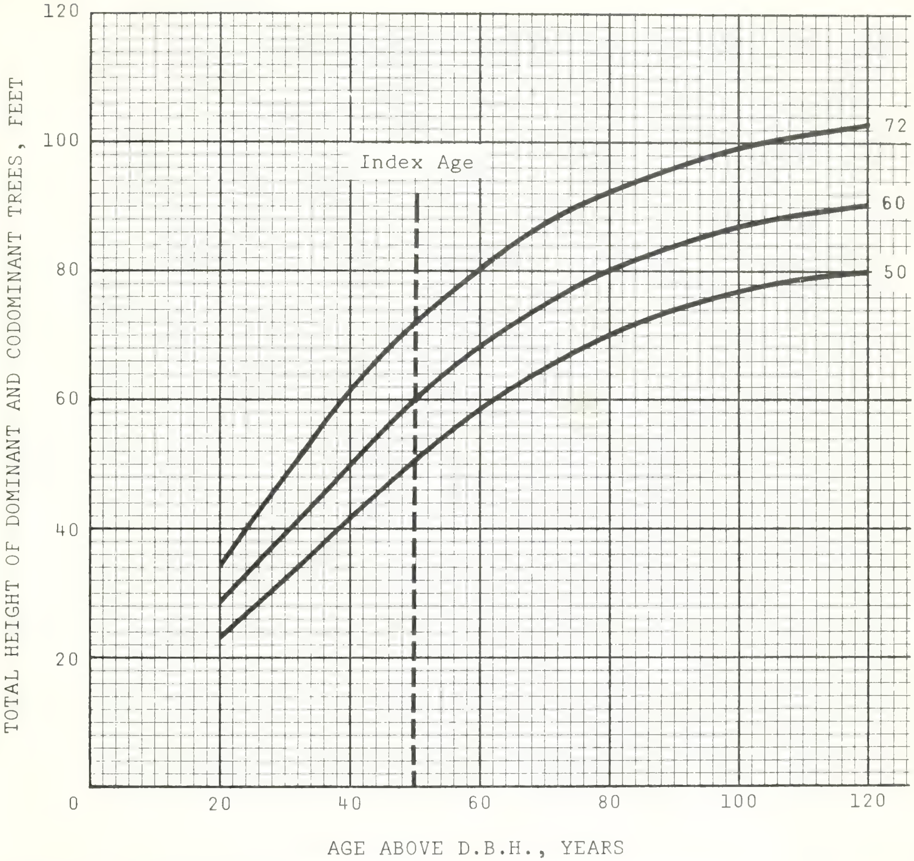
BASIS: Individual tree measurements on 111 sample plots.

RELIABILITY: No estimate.

SITE INDEX—4

HEIGHT/AGE CURVES

Natural Red and White Pine Stands—Canada



SOURCE: McCormack, R. J. GROWTH AND YIELD OF RED AND WHITE PINE. 1956. (Unpublished report of Canada Dept. North. Affairs and Natural Resources Forestry Br., as reported by Horton, K. W., and G. H. D. Bedell. WHITE AND RED PINE ECOLOGY, SILVICULTURE AND MANAGEMENT. Canada Dept. North. Affairs and Natural Resources Forestry Br. Bul. 124. 185 pp., illus., 1960.)

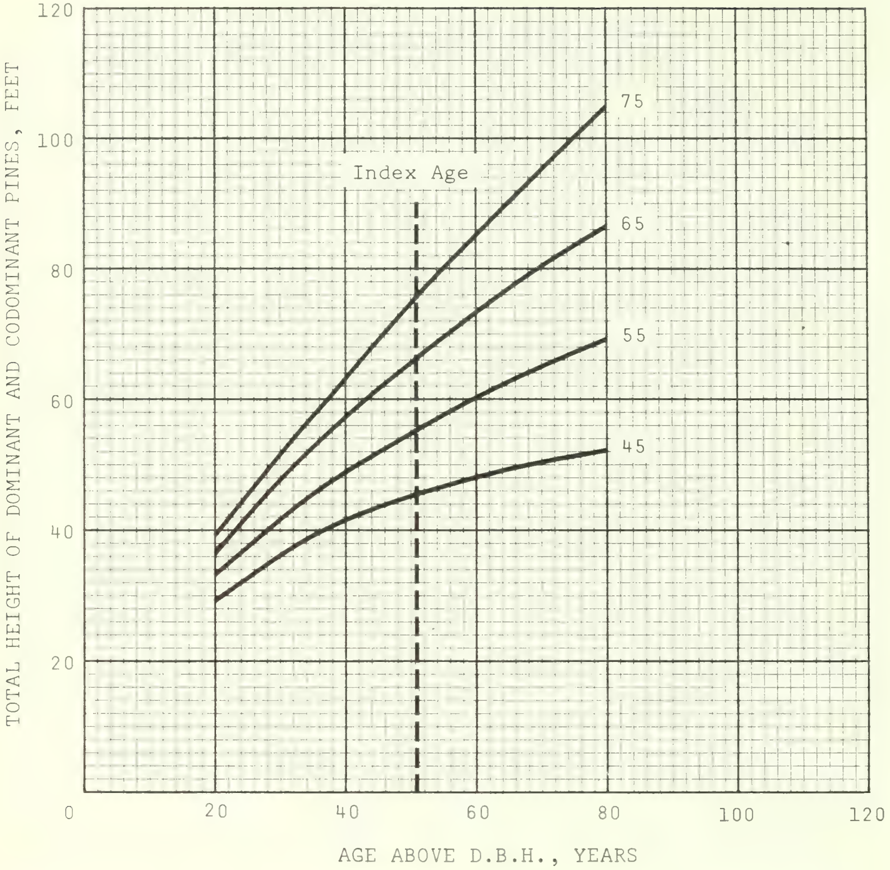
LOCATION: Ontario and Quebec.

BASIS: Measurements on 1,088 trees.

RELIABILITY: No estimate.

SITE INDEX—5

HEIGHT/AGE CURVES
Natural Stands—New Hampshire



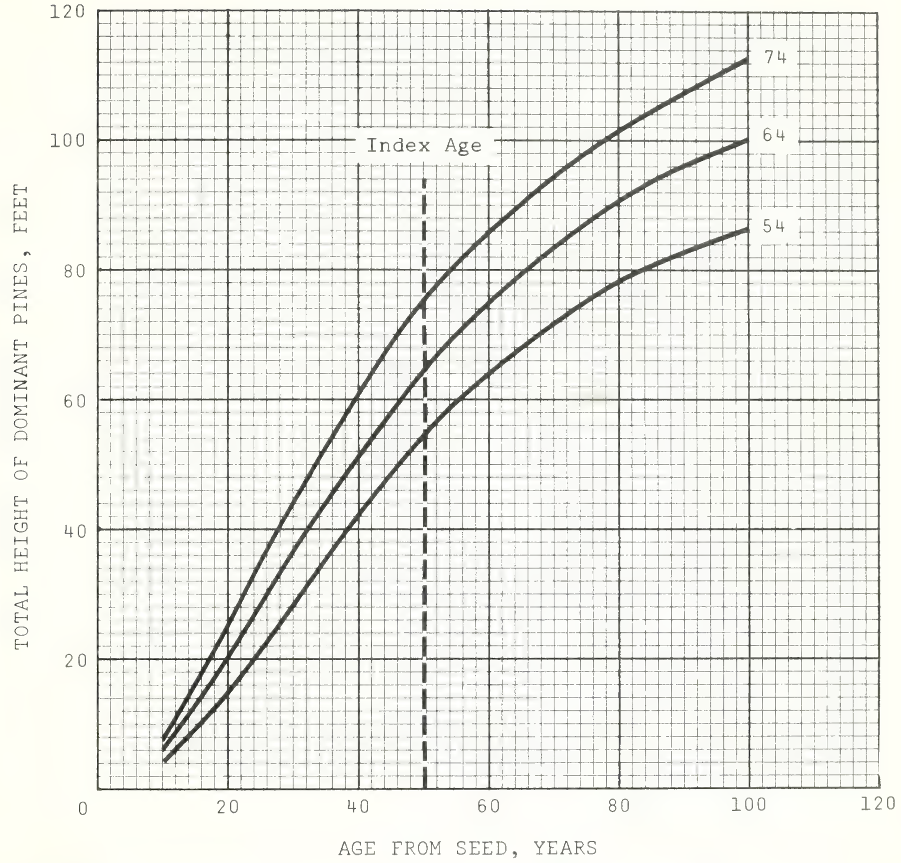
SOURCE: Husch, B. PRELIMINARY SITE INDEX TABLE FOR WHITE PINE IN SOUTHEASTERN NEW HAMPSHIRE. New Hamp. Agr. Expt. Sta. Forestry Mimeo. 1. 2 pp., illus., 1954.

LOCATION: Southeastern New Hampshire.

BASIS: 30 sample plots.

RELIABILITY: No estimate.

HEIGHT/AGE CURVES
Natural Stands—New Hampshire



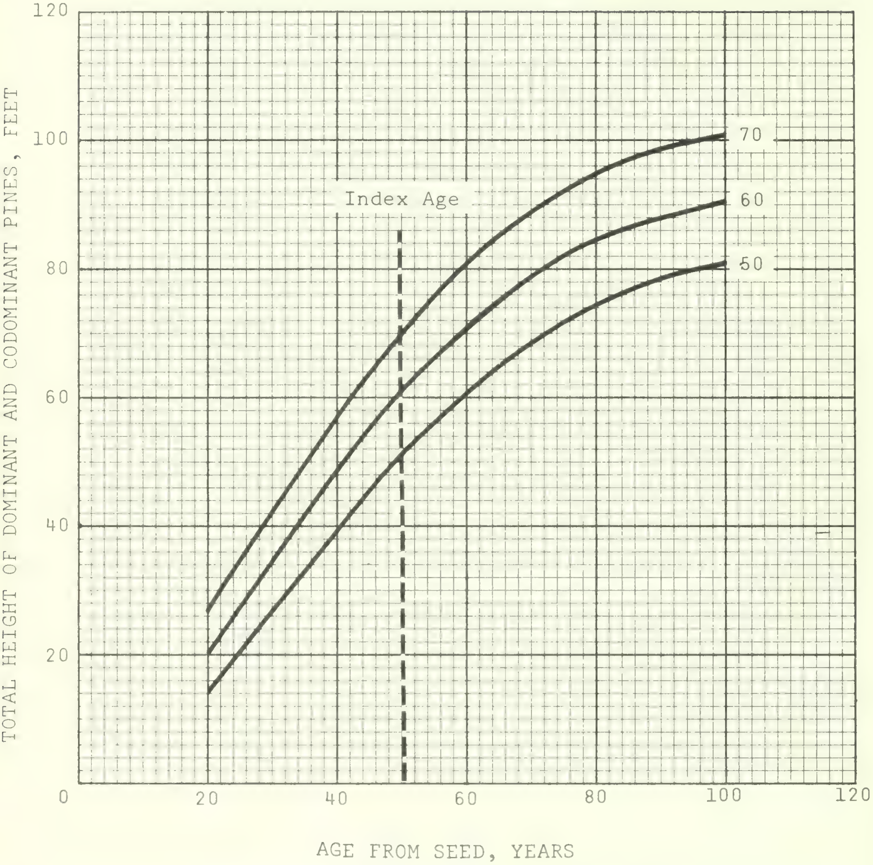
SOURCE: Frothingham, E. H. WHITE PINE UNDER FOREST MANAGEMENT. U. S. Dept. Agr. Bul. 13. 70 pp., illus., 1914.

LOCATION: New Hampshire.

BASIS: 196 plots.

RELIABILITY: No estimate.

SITE INDEX—7
HEIGHT/AGE CURVES
Natural Stands—Massachusetts



SOURCE: Spurr, Stephen H. FOREST INVENTORY. 476 pp., illus. Ronald Press, New York. 1952.

LOCATION: Massachusetts.

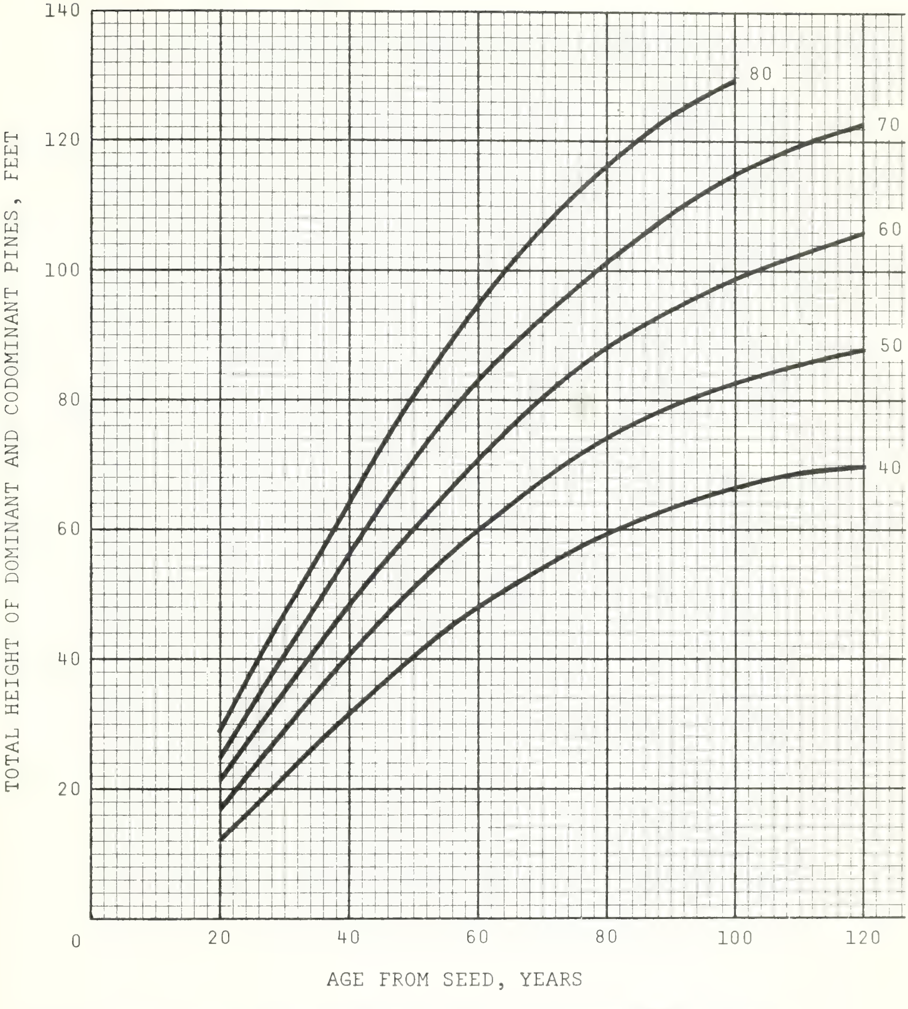
BASIS: Stem analyses and permanent sample-tree growth records for an unstated number of pines.

RELIABILITY: No estimate.

SITE INDEX—8

HEIGHT/AGE CURVES

Natural Stands—Lake States



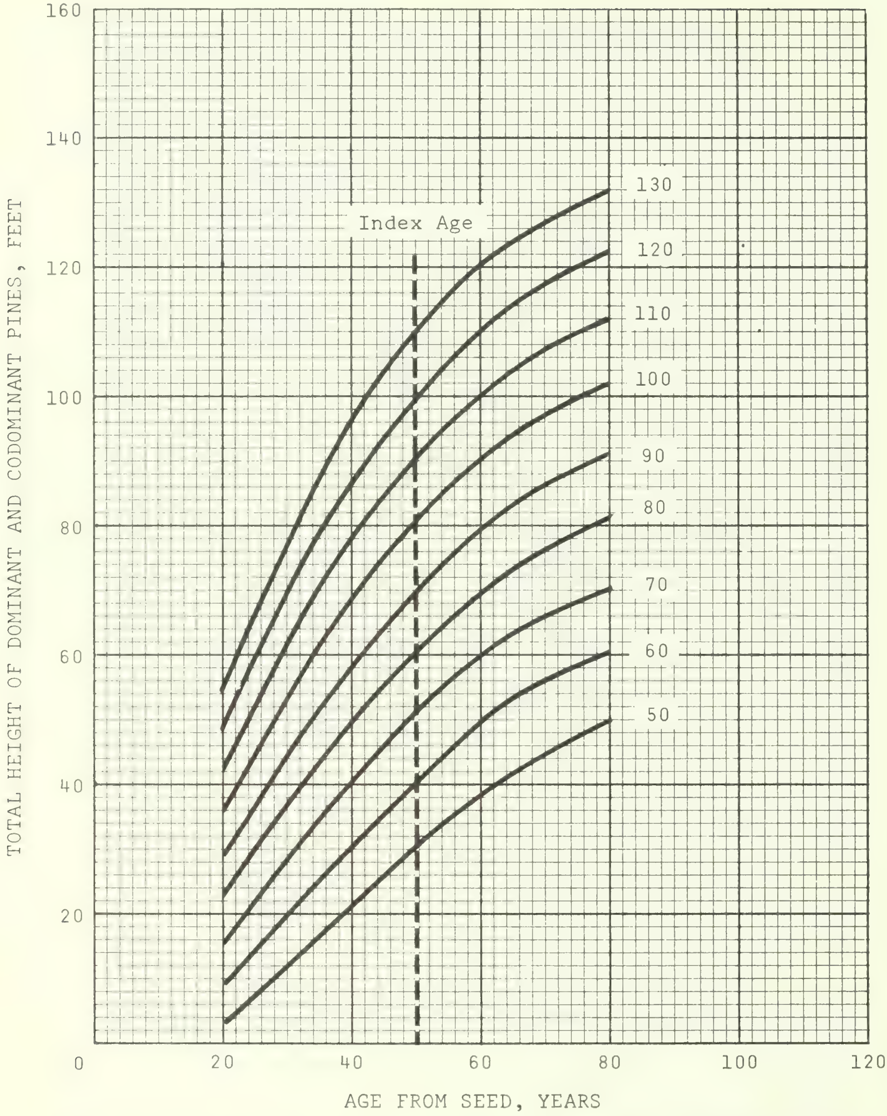
SOURCE: Gevorkiantz, S. R., and Raphael Zon. SECOND-GROWTH WHITE PINE IN WISCONSIN. Wis. Agr. Expt. Sta. Bul. 98. 40 pp., illus., 1930.

LOCATION: Northern Wisconsin.

BASIS: 92 plots.

RELIABILITY: No estimate.

SITE INDEX—9
HEIGHT/AGE CURVES
Natural Stands—Southern Appalachians



SOURCE: Doolittle, Warren T., and John P. Vimmerstedt. SITE INDEX CURVES FOR NATURAL STANDS OF WHITE PINE IN THE SOUTHERN APPALACHIANS. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 141. 2 pp., illus., 1960.

LOCATION: Western North Carolina and northern Georgia at elevations between 2,000 and 4,000 feet above sea level.

BASIS: 105 plots with 3 to 7 dominant and codominant trees per plot.

RELIABILITY: No estimate.

SITE INDEX—10
SOIL/SITE RELATION
Plantations—Ohio and Indiana

(Average height of dominant and codominant pine at 25 years)

A-horizon thickness	Silt and clay percent						
	30	40	50	60	70	80	90
Inches	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
4	43	43	42	41	41	40	39
6	50	49	49	48	48	47	46
8	54	53	53	52	51	50	49
10	57	56	55	54	54	53	52
12	59	58	57	56	55	54	53
14	60	59	58	57	57	56	55
16	61	60	59	58	57	56	55

SOURCE: Gaiser, Richard N., and Robert W. Merz. GROWTH OF PLANTED RED AND WHITE PINE IN OHIO AND INDIANA. U. S. Forest Serv. Central States Forest Expt.. Sta. Tech. Paper 134. 14 pp., illus., 1953.

LOCATION: Muskingum, Wellston, Zanesville soil association in parts of Ohio and Indiana.

BASIS: 100 sample plots.

RELIABILITY: No estimate.

SITE INDEX—11
SOIL/SITE RELATION
Natural Stands—Maine

(Average height of dominant and codominant pine at 50 years)

Volume of rocks in B horizon	Depth of A horizon in inches—							
	0	1	2	3	4	5	6	8
Percent	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
5	64	61	58	55	52	50	47	41
15	63	60	57	54	51	48	45	39
25	61	58	55	52	49	47	44	38
35	60	57	54	51	48	45	42	36
45	58	55	52	49	46	44	41	35

SOURCE: Young, Harold E. FOREST SOILS–SITE INDEX STUDY IN MAINE. Soil Sci. Soc. Amer. Proc. 18: 85-87. 1954.

LOCATION. Southern Maine.

BASIS: 16 sample areas.

RELIABILITY. Regression relation upon which this table is based accounted for 58 percent of the variation in site index.

SITE INDEX—12
INDICATOR PLANT RELATION
Natural Stands—Northeast

(White pine site index at 50 years)

Red maple age	Red maple height in feet —											
	20	25	30	35	40	45	50	55	60	65	70	75
Years	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
30	43	49	54	59	64	68	72	76	80	84	87	90
35	39	44	49	53	57	61	65	69	72	76	79	81
40	36	41	45	49	53	57	60	63	67	70	73	75
45	34	38	43	46	50	54	57	60	63	66	69	71
50	32	37	41	44	48	51	54	57	60	63	66	68
55	31	35	39	43	46	49	52	55	58	61	63	66
60	30	34	38	41	45	48	51	53	56	59	61	64
65	29	33	37	40	43	46	49	52	55	57	60	62
70	29	32	36	39	42	45	48	51	53	56	58	60
75	28	32	35	38	41	44	47	50	52	55	57	59
80	27	31	35	38	41	43	46	49	51	54	56	58

SOURCE: Foster, Ralph W. RELATION BETWEEN SITE INDICES OF EASTERN WHITE PINE AND RED MAPLE. Forest Sci. 5: 279-291. 1959. LOCATION: New York, Massachusetts, and Connecticut. BASIS: 70 observations. RELIABILITY: 7.7 percent standard error of estimate.

SITE INDEX—13
INDICATOR PLANT RELATION
Natural Stands—Southern Appalachians

(Comparative site indices at 50 years)

White pine	Virginia pine	White oak	Chestnut & red oaks	Short-leaf & pitch pine	Yellow-poplar
Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
60	54	47	52	44	40
70	63	55	60	53	55
80	72	63	70	63	72
90	81	72	79	73	87
100	90	81	88	83	103
110	99	90	97	92	118

SOURCE: Doolittle, Warren T. SITE INDEX COMPARISONS FOR SEVERAL FOREST SPECIES IN THE SOUTHERN APPALACHIANS. Soil Sci. Soc. Amer. Proc. 22: 455-458. 1958. LOCATION: Southern Appalachians. BASIS: 598 sample plots. RELIABILITY: Correlation coefficients for comparisons of two species range from 0.59 to 0.89, with standard errors of estimate of between 4 and 8 feet.

Tree Volume Estimators

A large number of tree volume estimators for white pine are presented in this section. Each of the five tables making up this section shows tree volume estimates of a particular type:

1. Cubic-foot volume by d.b.h. and total height.
2. Board-foot volume by d.b.h. and total height.
3. Board-foot volume by d.b.h. and merchantable length.
4. Board-foot volume by d.b.h., merchantable length and Girard form class.
5. Pulpwood volume above sawlog merchantability limits.

Most of these tables show volume estimates from several different sources. For example, the cubic-foot volume table shows as many as eight different estimates for each d.b.h. — total height class. The various sources in each table were chosen to reflect different merchantability standards, log rules, localities, and so forth. Thus the user has a variety of estimators from which to choose; and the grouping of sources helps to indicate the extent of variation that differing log rules, merchantability standards, and localities introduce. The various sources are cited and described at the end of each table.

Form-class volume tables require that the user determine average form class for his stands. Form-class often varies with diameter; so a minimum of 50 trees should be measured, representing all diameter classes to establish form-class averages.

TREE VOLUME—1
CUBIC-FOOT VOLUME
By Total Tree Height

(See footnotes for sources of data)

D.b.h. (inches)	Total volume					Merchantable volume		
	With bark		Without bark			4″ top		6″ top
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TOTAL TREE HEIGHT 10 FEET								
2	0.21	—	0.132	—	—	—	—	—
4	—	—	.547	—	—	—	—	—
20 FEET								
2	0.25	—	0.206	0.24	0.206	—	—	—
4	.99	—	.850	.90	.810	—	—	—
6	2.1	—	—	—	—	1.11	—	—
8	3.6	—	—	—	—	—	—	—
30 FEET								
2	0.31	—	0.28	0.35	0.31	—	—	—
4	1.38	—	1.17	1.33	1.24	—	—	—
6	3.0	3.0	2.67	2.90	2.74	1.94	2.6	—
8	5.2	5.4	4.80	5.04	—	3.86	4.5	—
10	8.4	8.6	7.58	—	—	—	—	—
40 FEET								
2	—	—	0.36	—	0.41	—	—	—
4	1.9	—	1.48	1.75	1.65	—	—	—
6	4.2	4.3	3.38	3.82	3.58	2.76	3.3	—
8	7.1	7.1	6.10	6.64	6.30	5.32	6.0	5.1
10	11.0	10.5	9.62	10.20	9.58	8.62	9.6	8.8
12	15.4	14.3	13.8	14.30	—	—	13.9	12.8
14	—	—	18.9	—	—	—	—	18.3
50 FEET								
4	—	—	1.78	—	2.05	—	—	—
6	5.6	5.1	4.07	4.73	4.52	3.58	4.3	—
8	9.3	8.8	7.34	8.21	7.72	6.79	7.8	6.2
10	13.9	13.1	11.60	12.50	12.10	10.91	12.0	10.7
12	18.8	18.0	16.80	17.70	17.20	—	17.6	15.9
14	24.5	23.7	23.00	23.70	23.50	—	23.7	21.6
16	30.6	30.7	30.30	30.20	—	—	30.5	28.0
18	37.0	40.0	38.50	—	—	—	—	35.3
20	44.0	—	47.70	—	—	—	—	—

CONTINUED

TREE VOLUME—1
CUBIC-FOOT VOLUME
By Total Tree Height

CONTINUED

D.b.h. (inches)	Total volume					Merchantable volume		
	With bark		Without bark			4″ top		6″ top
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				60 FEET				
4	—	—	—	—	2.46	—	—	—
6	—	6.0	4.79	—	5.41	4.41	—	—
8	11.7	10.5	8.65	9.80	9.19	8.25	9.8	7.2
10	17.4	15.8	13.5	14.90	14.5	13.19	15.0	12.6
12	23.5	22.0	19.7	21.00	20.6	19.24	21.1	19.0
14	30.7	29.1	27.0	28.10	28.0	—	28.7	26.1
16	38.3	37.5	35.4	36.00	36.9	—	36.5	34.0
18	46.9	47.6	45.1	45.00	46.5	—	44.6	42.7
20	56.3	—	55.9	—	—	—	52.9	52.5
22	66.1	—	—	—	—	—	—	63.0
24	76.2	—	—	—	—	—	—	74.2
26	—	—	—	—	—	—	—	86.3
28	—	—	—	—	—	—	—	99.0
				70 FEET				
6	—	6.5	5.5	—	6.3	5.23	—	—
8	14.5	12.2	9.9	—	10.8	9.72	12.0	8.3
10	21.5	18.9	15.6	—	16.8	15.48	17.9	14.6
12	29.1	26.4	22.8	24.30	24.0	22.53	25.3	21.8
14	37.9	34.8	31.2	32.50	32.8		32.5	30.0
16	47.5	44.3	40.9	41.80	42.6	—	42.3	39.3
18	58.3	55.5	52.2	52.00	53.4	—	52.6	49.6
20	69.7	67.1	64.7	—	65.2	—	63.2	60.5
22	81.6	79.1	78.6	—	77.2	—	74.9	72.4
24	93.6	—	94.2	—	90.0	—	87.1	85.0
26	—	—	110.0	—	—	—	—	98.8
28	—	—	—	—	—	—	—	113.3
30	—	—	—	—	—	—	—	129.0
				80 FEET				
6	—	—	—	—	7.1	—	—	—
8	—	13.9	—	—	12.2	11.8	—	—
10	26.0	21.9	—	—	19.3	17.77	20.9	—
12	35.2	30.8	25.7	—	27.4	25.83	29.8	24.7
14	45.8	40.2	35.1	—	37.5	35.35	39.6	34.0
16	58.0	51.0	46.2	—	48.3	—	49.8	44.6

CONTINUED

TREE VOLUME—1
CUBIC-FOOT VOLUME
By Total Tree Height

CONTINUED

D.b.h. (inches)	Total volume					Merchantable volume		
	With bark		Without bark			4″ top		6″ top
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
80 FEET, CONTINUED								
18	71.1	63.9	58.9	—	60.4	—	61.5	56.0
20	84.6	78.1	73.0	—	73.8	—	74.7	68.0
22	99.0	93.1	89.0	—	86.5	—	89.3	81.1
24	113.4	108.6	106.0	—	100.0	—	104.9	95.8
26	—	122.7	124.0	—	—	—	—	111.4
28	—	—	—	—	—	—	—	128.2
30	—	—	—	—	—	—	—	146.0
32	—	—	—	—	—	—	—	165.0
34	—	—	—	—	—	—	—	184.0
90 FEET								
8	—	15.8	—	—	13.6	—	—	—
10	—	25.0	—	—	21.5	20.06	—	—
12	42.2	35.0	28.6	—	30.7	29.12	33.7	—
14	55.1	45.8	39.1	—	41.9	39.83	43.6	—
16	69.6	58.1	51.4	—	54.0	—	55.9	—
18	85.4	72.2	65.6	—	67.3	—	69.1	62.7
20	101.8	88.1	81.3	—	81.5	—	84.8	76.6
22	118.2	105.3	98.7	—	95.4	—	101.4	91.1
24	134.6	121.8	117.0	—	110.0	—	119.0	107.0
26	—	137.8	138.0	—	—	—	—	124.0
28	—	—	—	—	—	—	—	142.5
30	—	—	—	—	—	—	—	162.0
32	—	—	—	—	—	—	—	182.0
34	—	—	—	—	—	—	—	204.0
100 FEET								
8	—	—	—	—	15.2	—	—	—
10	—	—	—	—	24.0	—	—	—
12	—	40.1	—	—	34.4	—	—	—
14	—	51.7	—	—	46.8	—	—	—
16	—	65.1	56.2	—	59.8	—	—	—
18	—	82.0	71.9	—	74.0	—	—	—
20	—	100.2	89.0	—	89.0	—	—	83.8
22	—	118.1	108.0	—	104.0	—	—	100.1
24	—	135.8	129.0	—	118.0	—	—	117.3
26	—	153.1	152.0	—	—	—	—	136.0

CONTINUED

CONTINUED

D.b.h. (inches)	Total volume					Merchantable volume		
	With bark		Without bark			4″ top		6″ top
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
100 FEET, CONTINUED								
28	—	—	—	—	—	—	—	157.0
30	—	—	—	—	—	—	—	179.0
32	—	—	—	—	—	—	—	202.0
34	—	—	—	—	—	—	—	225.0
110 FEET								
12	—	45.9	—	—	37.7	—	—	—
14	—	58.8	—	—	51.0	—	—	—
16	—	73.7	—	—	65.5	—	—	—
18	—	92.1	—	—	80.3	—	—	—
20	—	112.2	—	—	96.3	—	—	—
22	—	131.7	118.0	—	111.0	—	—	—
24	—	149.8	141.0	—	126.0	—	—	128.5
26	—	168.5	166.0	—	—	—	—	149.2
28	—	—	—	—	—	—	—	172.3
30	—	—	—	—	—	—	—	196.0
32	—	—	—	—	—	—	—	221.0
34	—	—	—	—	—	—	—	247.0
120 FEET								
18	—	—	—	—	86.6	—	—	—
20	—	125.6	—	—	103.0	—	—	—
22	—	146.7	129.0	—	118.0	—	—	—
24	—	165.5	154.0	—	133.0	—	—	—
26	—	183.2	181.0	—	—	—	—	—

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[1] SOURCE: Aughanbaugh, J. E., 1937, as reported by Delong, Thomas S., in YIELD AND STAND TABLES FOR PLANTATION WHITE PINE IN PENNSYLVANIA. Pa. Dept. Forests and Waters Note 8-b. 20 pp., ilus., 1955. *Location:* Pennsylvania. *Basis:* 898 trees. *Reliability:* Average deviation ±4.0 percent; aggregate difference 0.062 percent low. *Applicability:* Total volume, including stump, stem, top and bark.

[2] SOURCE: Frothingham, E. H. WHITE PINE UNDER FOREST MANAGEMENT. U. S. Dept. Agr. Bul. 13. 70 pp., illus., 1914. *Location:* New Hampshire. *Basis:* 1,568 trees. *Reliability:* No estimate. *Applicability:* Total volume, including stump, stem, top and bark.

[3] SOURCE: Anonymous. INTERPOLATED VOLUME TABLES FOR USE IN COMPILATION OF SAMPLE PLOT DATA. Canada Forest Serv. Misc. Series 3. 19 pp., illus., 1944. *Location:* Eastern Canada. *Basis:* No information. *Reliability:* No estimate. *Applicability:* Total volume.

[4] SOURCE: Olson, Richard A., Gordon Chapman, and Henry W. Hicock. CONNECTICUT VOLUME TABLES FOR PLANTATION GROWN WHITE PINE. Conn. Agr. Expt. Sta. Bul. 514. 23 pp.,

illus., 1948. *Location:* Connecticut. *Basis:* 1,031 trees 17 to 57 feet in total height, 1.7 to 15.0 inches in d.b.h. and 16 to 40 years old. *Reliability:* Average deviation ±4.92 percent; aggregate differences 0.11 percent low. *Applicability:* Total volume of stem less bark; 0.5-foot stump.

[5] SOURCE: Gevorkiantz, S. R. and Raphael Zon. SECOND-GROWTH WHITE PINE IN WISCONSIN. Wis. Agr. Expt. Sta. Bul. 98. 40 pp., illus., 1930. *Location:* Wisconsin. *Basis:* 105 trees. *Reliability:* Average deviation ±4.61 percent; aggregate difference 0.36 percent low. *Applicability:* Total volume of stump, stem, and top without bark.

[6] SOURCE: Vimmerstedt, John P. CUBIC-FOOT VOLUME TABLES FOR SOUTHERN APPALACHIAN WHITE PINE PLANTATIONS. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 162. 2 pp., illus., 1961. *Location:* Southern Appalachians. *Basis:* 241 trees. *Reliability:* Standard error of the mean volume was ±0.595 cubic feet. *Applicability:* Cubic-foot volume inside bark to a 4.0-inch i.b. top diameter.

[7] SOURCE. Frothingham, E. H. WHITE PINE UNDER FOREST MANAGEMENT. U. S. Dept. Agr. Bul. 13. 70 pp., illus., 1914. *Location:* Massachusetts. *Basis:* Not indicated. *Reliability:* No information. *Applicability:* Cubic-foot volume, including bark, between a 6-inch stump and a 4.0-inch o.b. top diameter.

[8] SOURCE: Demeritt, Dwight B. SECOND-GROWTH WHITE PINE VOLUME TABLE — SOUTHWESTERN MAINE. Univ. Maine Forestry Dept. Tech. Note 18. 5 pp., 1952. *Location:* Maine. *Basis:* 433 trees. *Reliability:* Average deviation ±6.5 percent; aggregate difference 0.82 percent low. *Applicability:* Cubic-foot volume excluding bark between a 1-foot stump and a 6-inch i.b. top diameter.

TREE VOLUME—2

BOARD-FOOT VOLUME

By Total Tree Height

(See footnotes for sources of data)

D. b. h. (inches)	Mill tally		International ¼-inch			Scribner		Maine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TOTAL TREE HEIGHT 30 FEET								
6	15	13	—	5	3	—	5	—
8	25	24	—	10	16	—	10	—
10	40	41	—	20	34	—	20	—
40 FEET								
6	20	20	—	10	8	—	8	—
8	35	36	25	15	24	25	17	25
10	55	53	45	35	45	40	31	40
12	75	73	60	55	72	55	48	60
14	100	95	—	80	105	—	67	—
16	—	—	—	—	145	—	—	—
50 FEET								
6	30	23	—	10	14	—	12	—
8	50	45	35	25	31	25	23	30
10	75	70	60	45	55	55	42	55
12	105	100	85	75	86	75	65	80
14	140	137	110	110	123	100	91	110
16	180	181	140	150	167	120	125	140
18	—	238	—	195	—	145	167	—
20	—	302	—	245	—	—	216	—
60 FEET								
6	—	27	—	15	19	—	16	—
8	65	53	40	30	39	30	30	40
10	95	85	75	60	66	65	54	70
12	135	125	110	95	100	95	82	105
14	175	173	150	140	141	130	116	145
16	230	230	190	190	189	165	159	190
18	295	297	235	250	—	205	212	240
20	380	379	290	315	—	255	274	290
22	—	—	360	—	—	315	—	350
24	—	—	430	—	—	385	—	410
26	—	—	—	—	—	470	—	470

CONTINUED

TREE VOLUME—2
BOARD-FOOT VOLUME
By Total Tree Height

CONTINUED

D. b. h. (inches)	Mill tally		International ¼-inch			Scribner		Maine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
70 FEET								
6	—	29	—	20	—	—	19	—
8	85	62	45	40	—	35	37	45
10	125	102	90	75	—	75	65	85
12	165	151	135	115	—	115	99	125
14	215	210	185	170	—	160	140	180
16	275	277	240	230	—	205	193	235
18	350	352	300	300	—	260	256	295
20	435	436	375	380	—	325	332	360
22	520	522	455	—	—	400	—	430
24	600	—	535	—	—	480	—	505
26	—	—	620	—	—	575	—	585
28	—	—	710	—	—	680	—	665
30	—	—	—	—	—	—	—	750
80 FEET								
6	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—
10	145	119	—	85	—	—	76	—
12	200	177	160	135	—	135	116	150
14	265	243	225	200	—	190	165	215
16	335	323	290	275	—	250	227	285
18	410	411	365	355	—	315	301	355
20	505	506	455	450	—	395	389	430
22	595	597	545	—	—	485	—	515
24	690	674	645	—	—	580	—	600
26	—	737	750	—	—	685	—	690
28	—	—	855	—	—	800	—	785
30	—	—	970	—	—	935	—	880
90 FEET								
10	—	138	—	—	—	—	—	—
12	230	200	—	160	—	—	134	—
14	310	277	265	230	—	—	190	—
16	380	370	340	315	—	295	261	335
18	475	475	435	410	—	380	345	415
20	580	583	535	515	—	470	446	505
22	680	681	640	—	—	570	—	600
24	780	769	750	—	—	680	—	695

CONTINUED

TREE VOLUME—2
BOARD-FOOT VOLUME
By Total Tree Height

CONTINUED

D. b. h. (inches)	Mill tally		International ¼-inch			Scribner		Maine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
90 FEET, CONTINUED								
26	885	846	870	—	—	795	—	800
28	—	—	1,000	—	—	925	—	905
30	—	—	1,160	—	—	1,070	—	1,010
100 FEET								
10	—	—	—	—	—	—	—	—
12	260	228	—	—	—	—	—	—
14	335	312	—	—	—	—	—	—
16	420	415	—	—	—	—	—	—
18	530	531	—	—	—	—	—	—
20	660	660	630	—	—	540	—	575
22	780	779	740	—	—	655	—	680
24	890	889	860	—	—	780	—	795
26	995	994	990	—	—	905	—	910
28	—	—	1,150	—	—	1,050	—	1,030
30	—	—	1,345	—	—	1,200	—	1,145
110 FEET								
12	—	245	—	—	—	—	—	—
14	—	348	—	—	—	—	—	—
16	—	479	—	—	—	—	—	—
18	—	610	—	—	—	—	—	—
20	—	750	—	—	—	—	—	—
22	—	887	—	—	—	—	—	—
24	—	1,030	960	—	—	880	—	890
26	—	1,180	1,125	—	—	1,015	—	1,020
28	—	—	1,300	—	—	1,170	—	1,145
30	—	—	1,530	—	—	1,335	—	1,270
120 FEET								
14	—	—	380	—	—	—	—	—
16	—	—	590	—	—	—	—	—
18	—	688	635	—	—	—	—	—
20	—	840	795	—	—	—	—	—
22	—	990	930	—	—	—	—	—
24	—	1,135	1,070	—	—	—	—	—
26	—	—	1,250	—	—	—	—	—

CONTINUED

TREE VOLUME—2
BOARD-FOOT VOLUME
By Total Tree Height

CONTINUED

D. b. h. (inches)	Mill tally		International ¼-inch			Scribner		Maine
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
130 FEET								
18	—	—	700	—	—	—	—	—
20	—	—	880	—	—	—	—	—
22	—	—	1,025	—	—	—	—	—
24	—	—	1,175	—	—	—	—	—
26	—	—	1,370	—	—	—	—	—
140 FEET								
26	—	—	1,500	—	—	—	—	—

[1] SOURCE: Frothingham, E. H. WHITE PINE UNDER FOREST MANAGEMENT. U. S. Dept. Agr. Bul. 13. 70 pp., illus., 1914. *Location:* Massachusetts. *Basis:* Not indicated. *Reliability:* No estimate. *Applicability:* 6-inch stump height, 4-inch i.b. minimum top diameter.

[2] SOURCE: Frothingham, E. H. WHITE PINE UNDER FOREST MANAGEMENT. U. S. Dept. Agr. Bul. 13. 70 pp., illus., 1914. *Location:* New Hampshire. *Basis:* 1,578 trees. *Reliability:* No estimate. *Applicability:* Merchantability limits not given; mill output averaged 30 percent dimension lumber and 70 percent boards, of which 60 percent were cut round-edged.

[3] SOURCE: Demeritt, Dwight B. SECOND-GROWTH WHITE PINE VOLUME TABLE — SOUTHWESTERN MAINE. Univ. Maine. Forestry Dept. Tech. Note 18. 5 pp., 1952. *Location:* Maine. *Basis:* 437 trees. *Reliability:* Average deviation, ±10.3 percent; aggregate difference, 0.32 percent low. *Applicability:* 1-foot stump height, and a 6-inch i.b. top diameter; no deduction for defect.

[4] SOURCE: Anonymous. FORM-CLASS VOLUME TABLES:. Canada Forest Service, Ottawa. 2nd Ed., 261 pp., 1948. *Location:* Ontario and New Brunswick. *Basis:* 522 trees. *Reliability:* No estimate. *Applicability:* 1.5-foot stump height; minimum top diameter of 6-8 inches increasing with d.b.h.; absolute form quotient of 70; trees less than 120 years old.

[5] SOURCE: Olson, Richard A., Gordon Chapman, and Henry W. Hicock. CONNECTICUT VOLUME TABLES FOR PLANTATION GROWN WHITE PINE. Conn. Agr. Expt. Sta. Bul. 514. 23 pp., illus., 1948. *Location:* Connecticut. *Basis:* 847 trees. *Reliability:* Average deviation ±8.7 percent; aggregate difference 0.33 percent low. *Applicability:* Stump height 0.5 feet; minimum top diameter 5.0 inches i.b.

[6] SOURCE: Demeritt, Dwight B. SECOND-GROWTH WHITE PINE VOLUME TABLE — SOUTHWESTERN MAINE. Univ. Maine. Forestry Dept. Tech. Note 18. 5 pp., 1952. *Location:* Maine. *Basis:* 434 trees. *Reliability:* Average deviation ±10.6 percent; aggregate difference 0.91 percent low. *Applicability:* Stump height 1 foot; minimum top diameter 6 inches i.b.; no deduction for defect.

[7] SOURCE: Anonymous. FORM–CLASS VOLUME TABLES. Canada Forest Service. Ottawa. 2nd Ed., 261 pp., 1948. *Location:* Ontario and New Brunswick. *Basis:* 522 trees. *Reliability:* No estimate. *Applicability:* Stump height, 1.5 feet; minimum top diameter 6-8 inches increasing with d.b.h.; absolute form quotient, 70; trees less than 120 years old.

[8] SOURCE: Demeritt, Dwight B. SECOND-GROWTH WHITE PINE VOLUME TABLE — SOUTHWESTERN MAINE. Univ. Maine. Forestry Dept. Tech. Note 18. 5 pp., 1952. *Location:* Maine. *Basis:* 433 trees. *Reliability:* Average deviation ±10.8 percent; aggregate difference 0.9 percent low. *Applicability:* Stump height 1 foot, scaled as utilized; defect deducted.

TREE VOLUME—3
BOARD-FOOT VOLUME
In Merchantable Lengths[1]

D. b. h. (inches)	International ¼-inch		Scribner	
	(2)	(3)	(4)	(5)
½ LOG				
8	6	—	7	—
10	11	—	11	—
12	16	—	16	—
14	23	—	22	—
16	30	—	29	—
1 LOG				
8	14	—	14	—
10	23	—	22	—
12	34	—	32	—
14	47	—	44	—
16	62	—	57	—
18	78	—	72	—
20	97	—	89	—
1½ LOGS				
8	22	26	21	28
10	35	34	33	34
12	52	—	48	—
14	71	—	65	—
16	93	—	86	—
18	118	—	108	—
20	146	—	134	—
22	177	—	162	—
24	211	—	193	—
26	248	—	226	—
2 LOGS				
8	30	40	29	34
10	48	51	45	42
12	69	64	64	51
14	95	—	87	64
16	125	—	114	—
18	158	—	144	—
20	196	—	178	—
22	237	—	216	—
24	282	—	257	—
26	331	—	301	—
28	385	—	349	—
30	442	—	401	—

CONTINUED

TREE VOLUME—3
BOARD-FOOT VOLUME
In Merchantable Lengths[1]

CONTINUED

D. b. h. (inches)	International ¼-inch		Scribner	
	(2)	(3)	(4)	(5)
		2½ LOGS		
8	38	52	36	47
10	60	68	56	60
12	87	86	80	77
14	119	109	109	94
16	156	131	143	116
18	198	—	181	—
20	245	—	223	—
22	296	—	270	—
24	353	—	321	—
26	415	—	377	—
28	481	—	437	—
30	553	—	501	—
32	629	—	570	—
34	710	—	644	—
36	796	—	722	—
		3 LOGS		
8	46	—	—	—
10	72	88	67	79
12	105	118	96	99
14	143	148	131	125
16	188	178	171	157
18	238	217	217	193
20	294	—	267	—
22	356	—	324	—
24	424	—	385	—
26	498	—	452	—
28	578	—	524	—
30	663	—	602	—
32	755	—	685	—
34	853	—	773	—
36	956	—	866	—
		3½ LOGS		
8	—	—	—	—
10	85	101	78	98
12	123	142	112	125
14	167	176	153	158

CONTINUED

CONTINUED

D. b. h. (inches)	International ¼-inch		Scribner	
	(²)	(³)	(⁴)	(⁵)
3½ LOGS, CONTINUED				
16	219	220	200	198
18	278	267	253	241
20	343	317	312	304
22	416	—	377	—
24	495	—	449	—
26	581	—	527	—
28	674	—	611	—
30	774	—	702	—
32	881	—	799	—
34	995	—	902	—
36	1,115	—	1,011	—
		4 LOGS		
10	97	—	89	—
12	140	167	128	152
14	192	213	175	193
16	251	260	228	240
18	318	316	289	304
20	392	373	357	380
22	475	—	431	—
24	566	—	513	—
26	664	—	603	—
28	771	—	699	—
30	885	—	802	—
32	1,007	—	913	—
34	1,137	—	1,030	—
36	1,275	—	1,155	—
		4½ LOGS		
12	158	195	144	180
14	216	244	197	225
16	282	303	257	288
18	358	367	325	364
20	442	441	401	450
22	535	525	485	544
24	637	—	578	—
26	748	—	678	—
28	867	—	786	—
30	996	—	903	—

CONTINUED

TREE VOLUME—3
BOARD-FOOT VOLUME
In Merchantable Lengths[1]

CONTINUED

D. b. h. (inches)	International ¼-inch		Scribner	
	(2)	(3)	(4)	(5)
4½ LOGS, CONTINUED				
32	1,133	—	1,027	—
34	1,279	—	1,159	—
36	1,435	—	1,300	—
		5 LOGS		
14	240	276	218	261
16	314	342	285	340
18	397	418	361	427
20	491	502	446	523
22	594	584	539	620
24	708	674	642	715
26	831	—	753	—
28	964	—	874	—
30	1,107	—	1,003	—
32	1,259	—	1,141	—
34	1,422	—	1,288	—
36	1,594	—	1,444	—
		5½ LOGS		
14	264	—	240	—
16	345	385	314	388
18	437	471	397	484
20	540	559	490	583
22	654	652	593	682
24	779	754	706	786
26	914	—	829	—
28	1,060	—	961	—
30	1,217	—	1,103	—
32	1,385	—	1,255	—
34	1,564	—	1,417	—
36	1,754	—	1,588	—
		6 LOGS		
16	377	425	342	440
18	477	520	433	540
20	589	615	535	641
22	714	719	647	745
24	849	828	770	860
26	997	—	904	—

CONTINUED

CONTINUED

D. b. h. (inches)	International ¼-inch		Scribner	
	([2])	([3])	([4])	([5])
6 LOGS, CONTINUED				
28	1,157	—	1,048	—
30	1,328	—	1,203	—
32	1,511	—	1,365	—
34	1,706	—	1,546	—
36	1,913	—	1,733	—
6½ LOGS				
18	—	569	—	590
20	639	669	579	694
22	773	783	701	809
24	920	900	834	940
26	1,080	—	979	—
28	1,253	—	1,136	—
30	1,439	—	1,304	—
32	1,637	—	1,483	—
34	1,849	—	1,674	—
36	2,073	—	1,877	—
7 LOGS				
20	—	724	—	740
22	834	848	755	862
24	991	977	898	1,000
26	1,164	—	1,054	—
28	1,350	—	1,223	—
30	1,550	—	1,404	—
32	1,763	—	1,597	—
34	1,991	—	1,803	—
36	2,232	—	2,022	—

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[1] Merchantable length is expressed in 8-foot half-logs and 16-foot logs.

[2] SOURCE: Bartoo, R. A., and R. J. Hutnik. BOARD FOOT VOLUME TABLES FOR TIMBER SPECIES IN PENNSYLVANIA. Pa. State Forest School. Res. Paper 30. 35 pp., 1962. *Location:* Pennsylvania. *Basis:* 187 trees. *Reliability:* Variation accounted for by estimating relation, 99.1 percent. *Applicability:* Stump height 1 foot; top diameter 6.0 inches inside back.

[3] SOURCE: Brown, R. M., and S. R. Gevorkiantz. VOLUME, YIELD, AND STAND TABLES FOR TREE SPECIES IN THE LAKE STATES. Minn. Agr. Expt. Sta. Tech. Bul. 39. 208 pp., illus., 1934. *Location:* Wisconsin. *Basis:* No information. *Reliability:* Average deviation ± 6.9 percent; aggregate difference 0.1 percent high. *Applicability:* Stump height 1 foot; top diameter 5 inches inside bark.

[4] SOURCE: Bartoo, R. A., and R. J. Hutnik. BOARD FOOT VOLUME TABLES FOR TIMBER SPECIES IN PENNSYLVANIA. Pa. State Forest School. Res. Paper 30 35 pp., 1962. *Location:* Pennsylvania. *Basis:* 187 trees. *Reliability:* Variation accounted for by estimating relation, 99.4 percent. *Applicability:* Stump height 1 foot; top diameter 6 inches inside bark.

[5] SOURCE: Gevorkiantz, S. R., and Raphael Zon. SECOND-GROWTH WHITE PINE IN WISCONSIN. Wis. Agr. Expt. Sta. Res. Bul. 98. 40 pp., illus., 1930. *Location:* Wisconsin. *Basis:* 105 trees. *Reliability:* Average deviation ± 7.42 percent; aggregate difference 0.08 percent high. *Applicability:* Stump height 1 foot; top diameter 6 inches inside bark.

TREE VOLUME—4

BOARD-FOOT VOLUME

Girard Form Class 66[1]

(International ¼-inch rule)

D.b.h. (inches)	Merchantable length, 16-foot logs						
	1	1½	2	2½	3	3½	4
10	24	31	—	—	—	—	—
12	38	49	57	—	—	—	—
14	53	69	81	90	—	—	—
16	74	96	111	125	—	—	—
18	95	124	145	163	178	—	—
20	119	156	183	206	224	—	—
22	146	191	225	253	277	298	—
24	176	231	272	306	337	363	—
26	211	276	325	366	404	437	—
28	246	322	379	429	473	511	546
30	284	373	441	496	547	593	633

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[1] In this table and the following tables based on form class, the sources of data based on the different log rules are as follows:

INTERNATIONAL ¼-INCH RULE: Bickford, C. Allen. Form–Class Volume Tables for Estimating Board-Foot Contents of Northern Conifers. U. S. Forest Serv. Northeast. Forest Expt. Sta., Sta. Paper 38. 33 pp., illus., 1951. *Location:* New England. *Basis:* Not indicated. *Reliability:* No information. *Applicability:* Minimum top diameter 6-inches inside bark.

MAINE RULE: Carl, Clayton M., and Harold E. Young. Form–Class Volume Tables for Estimating Board-Foot Contents of Northern Conifers — Maine Log Rule. Univ. Maine. Dept. Forestry Tech. Note 22. 4 pp., 1953. *Location:* New England. *Basis:* Based on data contained in Bickford volume tables, above. *Reliability:* No information. *Applicability:* Minimum top diameter 6-inches inside bark.

SCRIBNER RULE: Brown, R. M., and S. R. Gevorkiantz. Volume, Yield, and Stand Tables for Tree Species in the Lake States. Minn. Agr. Expt. Sta. Tech. Bul. 39. 208 pp., illus., 1934. *Location:* Lake States. *Basis:* 103 trees. *Reliability:* Average deviation ±4.5 percent; aggregate difference 0.2 percent. *Applicability:* Variable top diameter not less than 6 inches inside bark; stump height, 1 foot for trees less than 12 inches d.b.h., 1½ feet for trees 12 inches to 18 inches d.b.h., and 2 feet for trees over 18 inches d.b.h.

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 68

(International ¼-inch rule)

D. b. h. (inches)	Merchantable length, 16-foot logs						
	1	1½	2	2½	3	3½	4
10	26	33	—	—	—	—	—
12	41	52	61	—	—	—	—
14	58	75	88	98	—	—	—
16	78	102	120	134	148	—	—
18	100	133	156	176	193	—	—
20	127	167	197	222	243	262	—
22	157	205	243	273	301	324	—
24	188	247	293	330	364	394	—
26	224	294	348	394	435	471	502
28	260	344	408	462	510	553	592
30	302	399	472	534	591	641	686

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 70

D. b. h. (inches)	Merchantable length, 16-foot logs							
	1		1½		2		2½	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
10	28	31	36	—	—	—	—	—
12	43	46	56	59	66	72	73	—
14	62	65	81	82	95	99	107	—
16	83	86	109	108	129	130	144	147
18	108	111	142	139	168	167	189	188
20	136	140	179	174	212	209	238	242
22	166	171	219	212	261	254	294	288
24	200	206	264	256	314	306	355	346
26	237	244	313	302	372	361	422	406
28	278	286	367	354	437	423	495	477
30	321	331	425	410	504	488	572	551

D. b. h. (inches)	Merchantable length, 16-foot logs							
	3		3½		4		4½	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
16	159	164	—	—	—	—	—	—
18	208	210	224	—	—	—	—	—
20	262	274	284	—	—	—	—	—
22	325	322	350	349	375	376	—	—
24	392	385	426	418	454	451	—	—
26	466	452	506	493	541	534	—	—
28	548	531	596	576	638	622	—	—
30	635	614	690	668	740	721	783	—

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 72

D. b. h. (inches)	Merchantable length, 16-foot logs							
	1		1½		2		2½	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
10	30	33	39	43	45	53	—	—
12	46	49	60	63	72	77	80	—
14	66	69	87	88	102	106	116	—
16	88	91	116	116	138	140	155	158
18	115	119	151	149	179	179	203	203
20	144	148	191	186	227	223	256	252
22	176	181	234	226	279	272	316	307
24	213	219	282	274	336	328	382	370
26	251	259	333	322	398	386	452	437
28	296	305	390	379	466	453	530	512
30	341	351	453	436	539	522	614	590

D. b. h. (inches)	Merchantable length, 16-foot logs							
	3		3½		4		4½	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
14	127	—	—	—	—	—	—	—
16	171	176	—	—	—	—	—	—
18	224	227	242	—	—	—	—	—
20	283	282	306	—	327	—	—	—
22	350	342	378	373	405	404	—	—
24	422	411	459	449	491	487	—	—
26	501	488	545	531	584	574	621	—
28	588	571	640	622	687	672	729	—
30	681	659	743	718	797	777	846	—

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 74

D. b. h. (inches)	Merchantable length, 16-foot logs							
	1		1½		2		2½	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
10	32	35	42	46	49	56	—	—
12	50	52	65	66	78	81	87	—
14	71	73	93	93	110	113	125	128
16	93	97	123	123	147	149	167	169
18	121	125	160	158	191	191	217	216
20	153	157	203	198	242	238	275	270
22	188	193	250	242	297	291	338	330
24	226	233	300	292	359	350	409	396
26	266	274	354	344	424	414	482	468
28	311	321	414	402	496	483	566	546
30	361	372	481	465	574	558	656	633

D. b. h. (inches)	Merchantable length, 16-foot logs							
	3		3½		4		4½	5
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Int. ¼″
14	136	144	—	—	—	—	—	—
16	183	189	197	—	—	—	—	—
18	240	242	260	—	—	—	—	—
20	305	303	329	330	352	356	—	—
22	375	368	407	401	435	434	—	—
24	453	443	493	484	529	524	562	—
26	537	522	584	570	628	618	667	—
28	629	610	684	666	736	722	782	—
30	727	708	796	772	855	835	909	958

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 75

D. b. h. (inches)	Merchantable length, 16-foot logs							
	1		1½	2		2½	3	
	Int. ¼″	Scribner	Int. ¼″	Int. ¼″	Scribner	Int. ¼″	Int. ¼″	Scribner
8	—	12	—	—	—	—	—	—
10	33	25	43	50	40	—	—	—
12	51	42	67	80	69	89	—	—
14	72	63	95	113	105	128	141	131
16	97	86	127	152	144	173	190	182
18	125	113	165	197	191	224	249	240
20	157	144	209	250	245	284	315	309
22	193	177	258	307	302	350	388	383
24	232	—	309	370	—	422	469	—
26	275	—	365	438	—	499	556	—
28	321	—	426	512	—	585	650	—
30	371	—	495	592	—	678	752	—

D. b. h. (inches)	Merchantable length, 16-foot logs					
	3½	4		4½	5	
	Int. ¼″	Int. ¼″	Scribner	Int. ¼″	Int. ¼″	Scribner
14	—	—	162	—	—	—
16	205	—	232	—	—	—
18	270	288	306	—	—	—
20	341	365	392	—	—	430
22	422	452	488	479	—	538
24	510	548	—	582	—	—
26	606	651	—	692	—	—
28	708	763	—	811	—	—
30	824	886	—	943	994	—

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 76

D. b. h. (inches)	Merchantable length, 16-foot logs							
	1		1½		2		2½	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
10	34	37	45	48	52	60	—	—
12	52	55	69	71	83	87	92	—
14	74	77	98	98	117	120	132	136
16	100	104	132	132	157	160	179	182
18	129	133	171	169	204	205	232	232
20	162	166	216	209	258	252	294	288
22	198	203	266	256	317	310	362	352
24	237	244	319	308	382	371	436	422
26	284	292	377	367	452	442	516	501
28	331	341	439	428	528	515	604	584
30	381	394	510	494	611	595	700	676

D. b. h. (inches)	Merchantable length, 16-foot logs									
	3		3½		4		4½		5	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
14	146	153	—	—	—	—	—	—	—	—
16	197	203	214	—	—	—	—	—	—	—
18	258	258	280	282	299	305	—	—	—	—
20	326	324	354	352	379	381	—	—	—	—
22	402	394	437	430	469	465	498	—	—	—
24	485	472	528	515	567	558	603	—	—	—
26	575	560	628	613	675	666	717	—	—	—
28	672	653	733	715	790	777	840	825	886	880
30	778	757	852	827	917	897	977	956	1,031	1,016

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 78

D. b. h. (inches)	Merchantable length, 16-foot logs									
	1		1½		2		2½		3	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
10	36	39	48	51	56	63	63	—	—	—
12	56	59	74	76	88	93	98	106	109	119
14	78	81	104	104	124	127	140	146	156	164
16	106	109	141	139	168	169	192	192	212	216
18	136	140	182	178	217	217	248	247	276	277
20	171	176	229	224	275	271	313	309	348	347
22	211	217	282	274	337	332	387	378	430	424
24	252	259	338	328	406	396	463	452	517	507
26	299	308	400	389	480	470	550	534	614	599
28	347	358	464	452	560	546	642	622	716	698
30	403	416	540	524	648	633	744	721	830	809

D. b. h. (inches)	Merchantable length, 16-foot logs							
	3½		4		4½		5	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
14	167	—	—	—	—	—	—	—
16	231	236	247	256	—	—	—	—
18	300	302	321	328	—	—	—	—
20	379	378	407	409	431	—	—	—
22	467	462	503	501	535	—	—	—
24	563	552	606	598	644	—	681	—
26	672	656	722	713	768	760	814	806
28	783	764	844	829	898	886	948	942
30	909	885	980	961	1,045	1,026	1,104	1,090

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 80

D. b. h. (inches)	Merchantable length, 16-foot logs									
	1			1½		2			2½	
	Int. ¼″	Maine	Scribner	Int. ¼″	Maine	Int. ¼″	Maine	Scribner	Int. ¼″	Maine
8	—	—	15	—	—	—	—	—	—	—
10	39	42	30	51	55	60	68	48	68	—
12	59	62	50	78	80	93	99	81	105	113
14	83	86	74	110	111	133	136	121	151	155
16	112	115	101	149	148	178	180	168	204	206
18	144	148	131	193	190	231	231	219	265	264
20	181	186	166	242	237	291	288	279	333	329
22	221	228	204	297	290	357	351	344	410	401
24	266	274	—	357	348	431	422	—	494	482
26	315	324	—	423	411	509	498	—	585	568
28	367	379	—	493	480	595	582	—	683	664
30	424	438	—	571	554	687	671	—	791	766

D. b. h. (inches)	Merchantable length, 16-foot logs							
	3			3½		4		
	Int. ¼″	Maine	Scribner	Int. ¼″	Maine	Int. ¼″	Maine	Scribner
12	116	127	97	—	—	—	—	—
14	167	174	152	180	—	—	—	189
16	226	231	209	246	252	265	272	265
18	295	296	276	321	324	345	351	353
20	371	370	352	404	404	435	437	448
22	457	451	436	499	493	537	535	556
24	551	542	—	602	592	649	641	—
26	652	639	—	715	700	771	762	—
28	765	745	—	837	814	902	882	—
30	884	861	—	969	943	1,046	1,025	—

D. b. h. (inches)	Merchantable length, 16-foot logs				
	4½		5		
	Int. ¼″	Maine	Int. ¼″	Maine	Scribner
18	367	—	—	—	387
20	462	—	—	—	498
22	571	572	602	608	615
24	691	686	729	731	—
26	822	813	870	866	—
28	963	946	1,017	1,010	—
30	1,117	1,095	1,182	1,165	—

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 82

D. b. h. (inches)	Merchantable length, 16-foot logs									
	1		1½		2		2½		3	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
10	41	44	54	58	65	72	74	—	—	—
12	62	65	82	84	99	104	113	119	124	134
14	88	91	117	117	142	144	162	165	178	185
16	117	121	157	156	189	191	216	218	241	246
18	153	157	205	201	246	245	283	262	315	279
20	190	196	256	250	308	305	354	350	394	394
22	232	239	312	306	378	372	434	425	484	478
24	281	289	377	368	456	448	525	510	585	573
26	331	341	446	434	538	527	620	602	691	678
28	388	401	522	510	630	618	724	706	815	794
30	447	463	603	588	727	713	839	816	938	918

D. b. h. (inches)	Merchantable length, 16-foot logs							
	3½		4		4½		5	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
12	134	—	—	—	—	—	—	—
14	194	—	208	—	—	—	—	—
16	262	269	283	292	—	—	—	—
18	343	308	369	338	393	—	—	—
20	430	366	463	467	494	—	518	—
22	531	524	572	570	608	608	643	647
24	642	629	693	685	738	731	777	777
26	759	743	820	808	876	866	926	923
28	891	870	961	946	1,029	1,012	1,086	1,079
30	1,029	1,006	1,112	1,095	1,189	1,171	1,260	1,247

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 84

D. b. h. (inches)	Merchantable length, 16-foot logs									
	1		1½		2		2½		3	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
10	43	46	57	60	69	75	79	—	86	—
12	66	69	87	90	105	111	120	128	132	144
14	93	97	124	126	150	155	172	176	190	198
16	123	127	166	164	200	202	230	231	258	260
18	160	164	216	212	261	259	300	297	334	335
20	200	206	270	264	327	323	376	370	419	417
22	246	253	329	324	400	395	460	452	514	509
24	296	305	397	390	481	474	554	542	620	611
26	347	358	471	458	570	559	658	639	736	719
28	406	419	550	536	665	652	768	746	864	840
30	470	486	635	620	769	754	887	864	995	974

D. b. h. (inches)	Merchantable length, 16-foot logs							
	3½		4		4½		5	
	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine	Int. ¼″	Maine
12	144	—	—	—	—	—	—	—
14	207	—	221	—	—	—	—	—
16	280	285	301	310	321	—	—	—
18	365	366	393	397	419	—	—	—
20	460	448	495	480	527	—	557	—
22	564	558	609	607	650	648	687	688
24	681	672	739	732	785	781	829	830
26	809	790	875	862	936	922	989	982
28	946	923	1,024	1,006	1,097	1,078	1,160	1,150
30	1,094	1,070	1,184	1,166	1,267	1,248	1,343	1,329

TREE VOLUME—4
BOARD-FOOT VOLUME
Girard Form Class 85

D. b. h. (inches)	Merchantable length, 16-foot logs							
	1		1½	2		2½	3	
	Int. ¼″	Scribner	Int. ¼″	Int. ¼″	Scribner	Int. ¼″	Int. ¼″	Scribner
8	—	19	—	—	—	—	—	—
10	45	36	59	71	58	81	90	—
12	68	58	91	108	94	124	136	115
14	95	84	127	154	138	177	196	171
16	127	115	171	206	192	237	266	237
18	164	150	222	268	251	308	344	313
20	205	189	277	336	316	387	432	398
22	251	234	338	411	391	473	529	493
24	302	—	407	493	—	569	637	—
26	357	—	484	586	—	677	758	—
28	417	—	564	683	—	790	888	—
30	481	—	651	790	—	911	1,023	—

D. b. h. (inches)	Merchantable length, 16-foot logs					
	3½	4		4½	5	
	Int. ¼″	Int. ¼″	Scribner	Int. ¼″	Int. ¼″	Scribner
12	149	—	146	—	—	—
14	214	228	220	—	—	—
16	289	311	306	332	—	340
18	376	405	404	432	456	449
20	475	511	513	544	576	574
22	581	627	634	671	709	709
24	700	759	—	809	855	—
26	834	903	—	966	1,020	—
28	974	1,056	—	1,131	1,197	—
30	1,126	1,220	—	1,306	1,384	—

TOPWOOD VOLUME
4-Foot Bolts Above 8-Inch Top

D.b.h. (inches)	Volume from 8.0 inches i.b. to 4.0 inches i.b.		
	Cubic feet	Peeled cords	Rough cords
	1 BOLT		
27	1.161	0.012	0.014
28	1.177	.012	.014
29	1.192	.013	.014
30	1.205	.013	.014
	2 BOLTS		
17	1.977	0.021	0.023
18	2.040	.021	.024
19	2.094	.022	.025
20	2.139	.023	.025
21	2.178	.023	.026
22	2.212	.023	.026
23	2.242	.024	.026
24	2.268	.024	.028
25	2.291	.024	.027
26	2.311	.024	.027
27	2.329	.025	.027
28	2.345	.025	.028
29	2.360	.025	.028
30	2.373	.025	.028
	3 BOLTS		
15	2.981	0.031	0.035
16	3.071	.032	.036
17	3.146	.033	.037
18	3.209	.034	.038
19	3.263	.034	.038
20	3.308	.035	.039
21	3.347	.035	.039
22	3.381	.036	.040
23	3.411	.036	.040
24	3.437	.036	.040
25	3.460	.036	.041
26	3.480	.037	.041
27	3.498	.037	.041
28	3.514	.037	.041
29	3.529	.037	.041
30	3.542	.037	.042

CONTINUED

TREE VOLUME—5
TOPWOOD VOLUME
4-Foot Bolts Above 8-Inch Top

CONTINUED

D.b.h. (inches)	Volume from 8.0 inches i.b. to 4.0 inches i.b.		
	Cubic feet	Peeled cords	Rough cords
	4 BOLTS		
10	3.213	0.034	0.038
11	3.505	.037	.041
12	3.728	.039	.044
13	3.901	.041	.046
14	4.038	.043	.047
15	4.149	.044	.049
16	4.239	.045	.050
17	4.314	.045	.051
18	4.377	.046	.051
19	4.431	.047	.052
20	4.476	.047	.053
21	4.515	.047	.053
22	4.549	.048	.053
23	4.579	.048	.054
24	4.605	.049	.054
25	4.628	.049	.054
26	4.648	.049	.055
	5 BOLTS		
10	4.381	0.046	0.051
11	4.673	.049	.055
12	4.896	.051	.058
13	5.069	.053	.060
14	5.206	.055	.061
15	5.317	.056	.063
16	5.407	.057	.064
17	5.482	.058	.065
18	5.545	.058	.065
19	5.599	.059	.066
20	5.644	.059	.066
21	5.683	.060	.067
22	5.717	.060	.067
23	5.747	.061	.068
24	5.773	.061	.068
25	5.796	.061	.068
26	5.816	.061	.068

CONTINUED

TOPWOOD VOLUME
4-Foot Bolts Above 8-Inch Top

CONTINUED

D.b.h. (inches)	Volume from 8.0 inches i.b. to 4.0 inches i.b.		
	Cubic feet	Peeled cords	Rough cords
	6 BOLTS		
10	5.549	0.058	0.065
11	5.841	.061	.069
12	6.064	.064	.071
13	6.237	.066	.073
14	6.374	.067	.075
15	6.485	.068	.076
16	6.575	.069	.077
	7 BOLTS		
10	6.718	0.071	0.079
11	7.010	.074	.083
12	7.233	.076	.085
13	7.406	.078	.087
	8 BOLTS		
10	7.886	0.083	0.093
11	8.178	.086	.096

SOURCE: Carl, C. M., J. C. Mawson, and H. E. Young. WHITE PINE TOPWOOD VOLUME TABLES. Univ. Maine Dept. Forestry. Tech. Note 36. 4 pp., 1955.

LOCATION: Maine.

BASIS: 150 trees.

RELIABILITY: No information.

APPLICABILITY: To determine the pulpwood volume above sawlog merchantability limits.

Stand Growth and Yield Estimators

Much forest mensuration is aimed at developing projections of timber growth and yield. Such projections are usually based on two distinct analytical techniques: yield tables and stand tables. A yield table generally indicates the volume (or weight) of timber that will be available per unit area at various ages and for various site qualities. Yield table variants include:

Normal yield tables.—Provide estimates of yield based on standage and site quality for only the single stocking condition called normal stocking. Normal stocking is not a precise concept, but implies a fully occupied site and generally a number of trees per unit area in excess of the minimum number necessary to fully occupy the site.

Empirical yield tables.—Provide similar information, again for only a single level of stocking, but this time for the average level of stocking found on the sample plots that serve as the table's basis.

Variable-density yield tables.—Provide yield estimates for various stand densities as well as for various ages and site qualities.

Normal and empirical yield-table estimates of volume must be modified when they are applied to stands with non-normal or other-than-average densities. Methods of application for these cases are given in most standard forest mensuration texts. Yield tables usually include other information about stands beside volume, such as basal area, average height of trees, average number of trees, and average d.b.h.

A second approach to growth and yield estimation is provided by the stand table projection. Stand table projection is most often used to provide estimates of the increase in volume to anticipate for a short period in the future, in contrast to the long projections available from yield tables. Instead of relating yield to age, site, and density, the stand table projection relates change in yield to direct estimates of accretion, ingrowth, and mortality based on the average numbers of trees in various diameter classes, and their rates of diameter growth, height growth, and mortality. Stand table projections are often more precise estimates for short-term growth and yield than are yield tables.

All the growth and yield information presented here is presented on a per-acre basis, and all refers to second-growth rather than virgin stands.

STAND GROWTH—1
NORMAL YIELD TABLE
Natural Stands—New Hampshire

Stand age from seed	Average total height of dominants	All trees[1]			Gross volume		
					Total cubic feet		Board[4] feet
		Average d.b.h.	Number of trees	Basal area	Rough[2]	Peeled[3]	
Years	*Feet*	*Inches*	*No.*	*Sq. ft.*	*Cu. ft.*	*Cu. ft.*	*M bd. ft.*
50-YEAR SITE INDEX: 54							
10	4.0	1.0	2,408	14	530	420	—
20	14.5	2.3	2,060	60	1,350	1,130	—
30	28.5	3.9	1,676	139	2,450	2,060	5.3
40	42.5	5.5	1,118	183	3,780	3,180	14.2
50	54.0	7.0	764	204	5,200	4,370	24.1
60	64.0	8.6	543	219	6,530	5,490	33.6
70	71.5	10.1	412	229	7,760	6,520	42.3
80	78.0	11.7	318	238	8,820	7,410	50.1
90	83.0	13.2	258	245	9,750	8,190	57.0
100	87.0	14.5	219	251	10,530	8,845	62.8
50-YEAR SITE INDEX: 64							
10	6.0	1.4	2,015	20	650	550	—
20	19.5	3.2	1,626	90	1,750	1,470	—
30	36.5	5.1	1,192	169	3,250	2,730	9.6
40	51.5	7.1	760	209	5,130	4,310	23.5
50	64.0	8.9	537	232	7,000	5,880	36.6
60	74.5	10.7	397	248	8,500	7,140	46.9
70	83.0	12.4	311	261	9,840	8,270	56.1
80	90.0	14.1	251	272	10,930	9,180	64.0
90	95.5	15.7	210	282	11,850	9,950	70.9
100	100.0	17.1	182	290	12,630	10,610	77.0

CONTINUED

STAND GROWTH—1
NORMAL YIELD TABLE
Natural Stands — New Hampshire

CONTINUED

Stand age from seed	Average total height of dominants	All trees[1]			Gross volume		
		Average d.b.h.	Number of trees	Basal area	Total cubic feet		Board[4] feet
					Rough[2]	Peeled[3]	
50-YEAR SITE INDEX: 74.5							
10	7.2	1.7	1,728	29	800	670	—
20	24.5	4.0	1,322	115	2,100	1,760	4.5
30	44.0	6.4	879	196	4,000	3,360	13.9
40	61.0	8.6	583	235	6,500	5,460	32.8
50	74.5	10.8	408	260	8,800	7,390	49.1
60	85.5	12.8	311	278	10,500	8,820	60.2
70	94.5	14.7	249	293	11,900	10,000	69.9
80	101.5	16.5	207	307	13,000	10,920	77.8
90	108.0	18.2	177	319	14,000	11,760	84.8
100	113.0	19.8	154	330	14,700	12,350	91.2

[1] Minimum diameter not given but probably is 0.5 inch d.b.h.

[2] Total cubic-foot volume, including stump, stem, top, and bark of all trees 5.0 inches d.b.h. and over.

[3] Rough cubic-foot volume reduced by 16 percent.

[4] Based on a mill-tally volume table for New Hampshire, shown in TREE VOLUME — 1 in this report.

SOURCE: Frothingham, E. H. WHITE PINE UNDER FOREST MANAGEMENT. U. S. Dept. Agr. Bul. 13. 70 pp., illus., 1914. *Location:* New Hampshire. *Basis:* Observations in 196 normally stocked stands. *Reliability:* No estimate.

STAND GROWTH—2
NORMAL YIELD TABLE
Natural Stands—Wisconsin

Stand age from seed	Average total height of dominants	All trees 0.5 inches + d.b.h.				Trees 9.0 inches + d.b.h.[1]				Gross volume		
		Average total height	Average d.b.h.	Number of trees	Basal area	Average total height	Average d.b.h.	Number of trees	Basal area	Total		Merchantable
Years	*Feet*	*Feet*	*Inches*	*No.*	*Sq. ft.*	*Feet*	*Inches*	*No.*	*Sq. ft.*	*Cu. ft.*[2]	*M bd. ft.*[3]	*M bd. ft.*[4]
50-YEAR SITE INDEX: 50												
30	27	23	3.2	2,800	156	—	—	—	—	1,750	—	—
40	39	35	5.0	1,360	184	—	—	—	—	3,100	4.0	—
50	50	47	6.3	930	201	54	9.9	39	21	4,250	11.5	2.4
60	59	56	7.3	730	212	61	10.2	119	68	5,350	19.8	9.5
70	67	64	8.2	605	219	69	10.6	188	116	6,300	28.0	19.4
80	74	71	9.0	510	224	75	11.0	238	156	7,080	36.5	28.9
90	79	77	9.8	440	229	79	11.4	260	184	7,700	43.5	34.9
100	83	81	10.5	385	232	82	11.9	262	201	8,200	49.0	43.3
110	86	84	11.0	356	235	85	12.2	262	214	8,600	53.0	49.1
120	88	86	11.5	330	237	87	12.6	258	222	8,900	56.0	51.6
50-YEAR SITE INDEX: 60												
30	32	28	3.9	2,150	179	—	—	—	—	2,250	—	—
40	47	44	6.1	1,040	210	51	9.9	28	15	4,200	10.5	1.7
50	60	57	7.6	725	230	63	10.3	154	90	5,800	23.0	12.5
60	71	68	9.0	546	242	71	11.0	254	167	7,200	36.5	29.0
70	80	77	10.1	447	250	80	11.6	284	208	8,470	49.0	42.4

80	88	85	11.1	384	257	87	12.3	287	236	9,500	59.0	54.8
90	94	92	11.9	337	262	92	12.9	271	246	10,400	66.5	63.5
100	99	97	12.6	303	265	97	13.5	257	254	11,100	72.0	68.4
110	103	101	13.2	278	267	100	13.9	247	260	11,700	77.0	75.3
120	106	104	13.7	263	270	103	14.3	238	267	12,200	80.5	78.4

50-YEAR SITE INDEX: 70

30	38	34	4.3	1,800	188	—	—	—	—	2,900	—	—
40	55	52	6.7	890	221	59	10.1	70	39	5,150	15.5	5.4
50	70	68	8.5	613	242	73	10.7	227	143	7,200	34.5	25.9
60	82	80	9.9	475	255	83	11.5	288	207	9,000	51.5	43.5
70	93	91	11.2	386	263	93	12.4	293	244	10,570	66.0	61.7
80	103	101	12.3	327	271	102	13.2	274	259	11,900	77.0	72.8
90	110	109	13.3	284	275	108	14.0	252	270	12,950	85.0	84.3
100	115	114	14.2	255	280	112	14.8	235	279	13,750	91.5	97.9
110	120	119	14.9	235	283	117	15.4	221	286	14,400	96.5	105.4
120	123	122	15.4	220	285	119	15.8	209	286	14,900	100.0	108.5

[1] An extension of data originally presented.

[2] Total cubic-foot volume including stump, stem, and top, but excluding bark, as reported.

[3] All trees 7.0 inches d.b.h. and above based on International 1/8-inch log rule, 1-foot stump, and 5.0-inch top diameter inside bark, as reported.

[4] All trees 9.0 inch d.b.h. and over based on International 1/4-inch log rule, 1-foot stump, and 6.0-inch top diameter inside bark, not reported by source.

SOURCE: Gevorkiantz, S. R., and Raphael Zon. SECOND-GROWTH WHITE PINE IN WISCONSIN. Wis. Agr. Expt. Sta. Bul. 98. 40 pp., illus., 1930. *Location:* Northern Wisconsin. *Basis:* 92 sample plots varying from 1/10 to 3/10 acre. *Reliability:* No estimate.

STAND GROWTH—3
NORMAL YIELD TABLE
Natural Stands—Southern Appalachians

Age	Basal area	Volume[1]		Age	Basal area	Volume[1]	
Years	*Sq. ft.*	*Cu. ft.*	*Bd. ft.*	*Years*	*Sq. ft.*	*Cu. ft.*	*Bd. ft.*
SITE 50				SITE 80			
30	125	1,400	—	30	155	2,825	—
40	147	2,480	3,200	40	181	4,880	16,240
50	161	3,400	9,220	50	200	6,800	34,720
60	170	4,280	15,840	60	210	8,600	47,680
70	175	5,040	22,400	70	218	10,080	60,800
80	179	5,664	29,200	80	225	11,320	70,400
90	183	6,160	34,800				
100	186	6,560	39,200				
SITE 60				SITE 90			
30	143	1,800	—	30	158	3,280	—
40	168	3,360	8,400	40	183	5,560	20,800
50	184	4,640	18,400	50	203	7,680	41,040
60	194	5,760	29,200	60	214	9,920	57,600
70	200	6,776	39,200	70	223	11,600	72,400
80	206	7,600	47,200	80	231	12,960	82,400
90	210	8,320	53,200				
100	212	8,880	57,600				
SITE 70				SITE 100			
30	150	2,320	—	30	161	3,700	—
40	177	4,120	12,400	40	185	6,160	24,800
50	194	5,760	27,600	50	205	8,400	46,400
60	204	7,200	41,200	60	216	11,144	66,720
70	211	8,456	52,800	70	226	12,920	82,400
80	217	9,520	61,600	80	235	14,400	92,560

[1] Cubic-foot volume includes all trees. Board-foot volume includes trees above 7 inches d.b.h. utilized to a 5-inch top diameter. Volumes do not include bark.

SOURCE: Doolittle, W. T. YIELD TABLES FOR WHITE PINE. (Unpublished data adapted from Gevorkiantz, S. R. and Raphael Zon. SECOND GROWTH WHITE PINE IN WISCONSIN. Wis. Agr. Expt. Sta. Res. Bul. 98, 40 pp., illus., 1930.) U. S. Forest Serv. Southeast. Forest Expt. Sta., 1956. *Location:* Southern Appalachians. *Basis:* Wisconsin data reported by Gevorkiantz and Zon. *Reliability:* No estimate.

STAND GROWTH—4

EMPIRICAL YIELD TABLE

4 x 4-foot Plantations—Pennsylvania

Stand age from planting	Average total height of dominants and co-dominants	All trees 1.0 inch + d.b.h.				Volume	
		Average d.b.h.	Average total height	Number of trees	Basal area	Total[1]	Merchantable[2]
Years	*Feet*	*Inches*	*Feet*	*No.*	*Sq. ft.*	*Cu. ft.*	*Cords*
50-YEAR SITE INDEX: 40							
15	11	2.0	13.9	1,001	20.0	658	—
20	16	2.7	17.4	2,519	97.0	1,007	—
25	20	3.3	20.5	2,324	135.0	1,456	0.5
30	24	3.8	23.7	1,991	157.3	1,975	2.6
35	29	4.3	27.8	1,697	171.4	2,498	5.6
40	33	4.8	31.6	1,424	179.0	3,011	9.4
45	38	5.2	35.1	1,228	181.3	3,461	13.8
50	40	5.5	37.4	1,083	181.3	3,838	17.1
55	42	5.8	39.4	1,006	181.3	4,177	19.3
50-YEAR SITE INDEX: 50							
15	14	2.5	15.5	1,326	43.1	780	—
20	20	3.2	20.0	2,071	116.0	1,330	0.2
25	26	3.8	24.4	1,882	150.9	1,977	2.6
30	31	4.4	29.0	1,611	171.0	2,684	6.3
35	36	5.0	34.5	1,372	183.2	3,393	10.4
40	41	5.5	39.6	1,148	189.4	4,079	16.2
45	46	6.0	44.1	976	191.2	4,692	22.2
50	50	6.5	47.5	840	191.2	5,210	27.6
55	54	6.7	50.2	774	191.2	5,656	32.5
50-YEAR SITE INDEX: 60							
15	18	2.9	17.0	1,369	64.2	929	—
20	24	3.7	22.5	1,784	132.4	1,723	1.4
25	30	4.4	28.2	1,570	164.9	2,609	5.9
30	37	5.0	34.2	1,322	183.0	3,549	12.1
35	43	5.7	41.1	1,101	193.6	4,482	19.8
40	50	6.3	47.5	919	198.9	5,377	27.9
45	55	7.0	53.0	759	199.9	6,185	35.0
50	60	7.5	57.6	651	199.9	6,869	41.4
55	64	8.0	60.9	576	199.9	7,454	47.0
50-YEAR SITE INDEX: 70							
15	21	3.3	18.6	1,386	82.9	1,076	0.2
20	30	4.2	25.1	1,543	146.3	2,110	3.6

CONTINUED

STAND GROWTH—4
EMPIRICAL YIELD TABLE
4 x 4-foot Plantations—Pennsylvania

CONTINUED

Stand age from planting	Average total height of dominants and co-dominants	All trees 1.0 inch + d.b.h.				Volume	
		Average d.b.h.	Average total height	Number of trees	Basal area	Total[1]	Merchantable[2]
50-YEAR SITE INDEX: 70, CONTINUED							
25	38	5.0	32.1	1,324	176.8	3,231	10.4
30	44	5.7	39.4	1,104	192.8	4,399	19.5
35	51	6.4	47.7	900	202.5	5,553	30.0
40	58	7.2	55.4	729	206.7	6,655	40.1
45	64	8.0	62.0	594	207.3	7,654	48.6
50	70	8.8	67.6	489	207.3	8,505	56.0
55	75	9.6	71.8	412	207.3	9,224	62.7
50-YEAR SITE INDEX: 80							
15	25	3.7	20.1	1,266	97.0	1,208	0.9
20	34	4.6	27.7	1,342	157.6	2,458	6.2
25	43	5.5	35.9	1,142	186.4	3,793	15.1
30	51	6.3	44.6	932	201.3	5,166	26.5
35	59	7.2	54.3	736	209.6	6,519	40.3
40	66	8.2	63.3	582	213.1	7,806	52.5
45	72	9.3	71.0	453	213.3	8,978	62.3
50	80	10.5	77.6	357	213.3	9,980	70.4
55	85	11.6	82.5	288	213.3	10,819	78.2
50-YEAR SITE INDEX: 90							
Years	Feet	Inches	Feet	No.	Sq. ft.	Cu. ft.	Cords
15	28	4.2	21.7	1,098	104.1	1,332	1.9
20	38	5.1	30.2	1,156	164.2	2,787	8.5
25	48	6.0	39.7	992	192.0	4,322	19.5
30	57	6.9	49.8	793	206.1	5,890	33.5
35	66	7.9	60.9	624	213.8	7,435	50.6
40	75	9.2	71.1	474	216.8	8,894	64.1
45	84	10.7	79.9	349	216.8	10,236	74.5
50	90	12.3	87.6	262	216.8	11,375	83.4
55	95	14.1	92.3	203	216.8	12,327	91.3

[1] Total cubic-foot volume including stump, stem and bark, but not limbwood.

[2] Rough cords to a variable top of not less than 4.0 inches i.b., and a 1-foot stump.

SOURCE: Delong, Thomas S. YIELD AND STAND TABLES FOR PLANTATION WHITE PINE IN PENNSYLVANIA. Pa. Dept. Forests and Waters Note 8-b., 1955. *Location:* Data from 8 counties in eastern and central Penna. *Basis:* Remeasurement data on 22 sample plots from 1/10 to 1/4 acre, in white pine plantations with spacings from 3½ x 3½ feet to 5 x 5 feet. *Reliability:* Standard errors of estimate range from 5 to 13 percent for various statistics.

STAND GROWTH—5

EMPIRICAL YIELD TABLE

Mixed Red and White Pine—Canada

Age above breast height	Average total height		Volume per square feet of basal area[1]			Average basal area[2]	Average volume per acre[1]		
	Dominants	All trees	Total cubic feet	Merchantable cubic feet	Merchantable board feet		Total cubic feet	Merchantable cubic feet	Merchantable board feet
Years	*Feet*	*Feet*	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Sq. ft.*	*Cu. ft.*	*Cu. ft.*	*M bd. ft.*
				50-YEAR SITE INDEX:	40				
20	20	—	—	—	—	50	—	—	—
40	33	25	14.8	7.1	15	93	1,376	660	1.4
60	46	36	17.8	11.1	28	106	1,887	1,177	3.0
80	55	44	20.3	14.5	43	110	2,233	1,595	4.7
100	60	49	22.2	16.7	55	115	2,553	1,921	6.3
120	65	54	24.2	19.0	66	118	2,856	2,242	7.8
140	67	57	25.3	20.3	75	122	3,087	2,477	9.2
160	69	59	26.2	21.4	81	126	3,301	2,696	10.2
180	70	60	26.7	21.9	84	130	3,471	2,847	10.9
200	71	61	27.0	22.3	87	133	3,591	2,966	11.6

CONTINUED

STAND GROWTH—5
EMPIRICAL YIELD TABLE
Mixed Red and White Pine—Canada

STAND GROWTH—5

EMPIRICAL YIELD TABLE

Mixed Red and White Pine—Canada

CONTINUED

Age above breast height	Average total height		Volume per square feet of basal area[1]			Average basal area[2]	Average volume per acre[1]		
	Dominants	All trees	Total cubic feet	Merchantable cubic feet	Merchantable board feet		Total cubic feet	Merchantable cubic feet	Merchantable board feet
Years	*Feet*	*Feet*	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Sq. ft.*	*Cu. ft.*	*Cu. ft.*	*M bd. ft.*
				50-YEAR SITE INDEX: 50					
20	25	—	—	—	—	69	—	—	—
40	43	33	16.8	9.9	24	121	2,033	1,198	2.9
60	58	47	21.5	15.8	49	126	2,709	1,991	6.2
80	69	59	26.2	21.4	81	130	3,406	2,782	10.5
100	75	66	29.1	24.8	105	135	3,929	3,348	14.2
120	80	72	31.9	27.6	124	138	4,402	3,809	17.1
140	83	76	33.8	29.8	140	143	4,833	4,261	20.0
160	85	79	35.2	31.2	153	147	5,174	4,586	22.5
180	86	80	35.6	31.8	157	151	5,376	4,802	23.7
200	87	81	36.1	32.3	161	155	5,595	5,006	25.0
				50-YEAR SITE INDEX: 60					
20	30	*22	14.2	6.2	13	99	*1,406	*614	*1.3
40	52	42	19.7	13.6	39	155	3,054	2,108	6.0
60	68	57	25.3	20.3	75	161	4,073	3,268	12.1
80	78	69	30.6	26.3	114	166	5,080	4,366	18.9
100	85	79	35.1	31.2	152	172	6,037	5,366	26.1
120	90	85	38.0	34.2	179	177	6,726	6,053	31.7
140	93	88	39.2	35.6	190	183	7,174	6,515	34.8

160	95	90	40.1	36.5	196	189	7,579	6,899	37.0
180	97	92	40.8	37.2	202	194	7,915	7,217	39.2
200	98	93	41.2	37.6	205	200	8,240	7,520	41.0
50-YEAR SITE INDEX: 70									
20	37	28	15.5	8.1	18	113	1,752	915	2.0
40	61	50	22.6	17.1	56	170	3,842	2,907	9.5
60	79	71	31.5	27.3	121	176	5,544	4,805	21.3
80	90	85	38.0	34.2	179	179	6,916	6,224	32.6
100	98	93	41.2	37.6	205	188	7,746	7,069	38.5
120	103	*97	42.5	39.1	215	194	*8,245	*7,585	*41.7
140	106	*99	43.1	39.6	219	200	*8,620	*7,920	*43.8
160	109	*100	43.4	40.0	222	206	*8,940	*8,240	*45.7
180	111	*101	43.7	40.2	223	212	*9,264	*8,522	*47.3
200	112	*102	43.9	40.4	224	218	*9,570	*8,807	*48.8

* Extrapolations of data.

[1] Merchantable board-foot volume is based on the Ontario log rule. Other volumes measured are not defined in this source, nor are merchantability limits given.

[2] Estimates of present and future volume for stands of other than average basal area, and/or with intermediate site indices, are made as follows: A. Using the table closest to the age-dominant height relationship observed in the stand of interest, determine the average volume per square foot of basal area that corresponds to the observed dominant height. For example, if a 64-year-old stand has a dominant height of 73 feet, the site-index 60 table indicates an average total cubic-foot volume per square foot of basal area of 28.0 for a dominant height of 73 feet, by interpolation. This average multiplied by the observed basal area provides the adjusted estimate of present volume. B. Compute the percentage differences in dominant height and basal area that exist now from observed and table values. Apply these percentages to the table values for dominant height and basal area for the future **age** of interest, and proceed as above to estimate an adjusted future volume. This projection assumes that the relative degree of normal stocking will be maintained, and so should be modified for long projection periods.

SOURCE: McCormack, R. J. 1956. GROWTH AND YIELD OF RED AND WHITE PINE. (Unpublished report of the Canada Dept. North. Affairs and Natural Resources, Forestry Br.; as reported by Horton, K. W. and Bedell, G. D. H. 1960. WHITE AND RED PINE ECOLOGY, SILVICULTURE AND MANAGEMENT. Canada Dept. North. Affairs and Natural Resources, Forestry Br. Bul. 124. 185 pp., illus.) *Location:* Ontario and Quebec. *Basis:* More than 500 one-fifth acre plots. *Reliability:* No estimate.

STAND GROWTH—6
VARIABLE DENSITY YIELD TABLE
Plantations—Southern Appalachians

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
		25-YEAR SITE INDEX: 45		
		Original spacing 4' x 4'		
10	15	3.1	298	—
15	28	3.7	1,171	—
20	38	4.2	2,150	—
25	45	4.7	2,958	1,542
30	51	5.2	3,548	3,581
35	55	5.7	3,955	5,650
		Original spacing 5' x 5'		
10	15	3.5	249	—
15	28	4.1	1,040	—
20	38	4.6	1,967	557
25	45	5.2	2,754	2,311
30	51	5.7	3,344	4,435
35	55	6.3	3,758	6,561
		Original spacing 6′ x 6′		
10	15	3.8	226	—
15	28	4.4	975	—
20	38	5.0	1,874	1,016
25	45	5.6	2,650	2,912
30	51	6.2	3,237	5,137
35	55	6.7	3,656	7,332
		Original spacicng 6′ x 7′		
10	15	3.9	219	—
15	28	4.6	955	—
20	38	5.2	1,845	1,199
25	45	5.8	2,617	3,157
30	51	6.5	3,205	5,427
35	55	7.1	3,623	7,659
		Original spacing 7′ x 7′		
10	15	4.1	213	—
15	28	4.7	938	86
20	38	5.4	1,820	1,388
25	45	6.0	2,589	3,411
30	51	6.7	3,175	5,736
35	55	7.4	3,596	8,003

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CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
Original spacing 8′ x 8′				
10	15	4.3	205	—
15	28	5.1	914	257
20	38	5.7	1,786	1,702
25	45	6.4	2,550	3,848
30	51	7.1	3,135	6,256
35	55	7.8	3,557	8,586
Original spacing 9′ x 9′				
10	15	4.6	200	—
15	28	5.3	898	403
20	38	6.1	1,763	1,974
25	45	6.8	2,524	4,231
30	51	7.5	3,108	6,728
35	55	8.3	3,531	9,117
Original spacing 10′ x 10′				
10	15	4.8	196	—
15	28	5.6	888	531
20	38	6.4	1,747	2,217
25	45	7.1	2,504	4,575
30	51	7.9	3,089	7,150
35	55	8.7	3,512	9,588
Original spacing 12′ x 12′				
10	15	5.2	192	6
15	28	6.1	873	753
20	38	6.9	1,725	2,640
25	45	7.8	2,481	5,175
30	51	8.6	3,065	7,883
35	55	9.5	3,487	10,449
25-YEAR SITE INDEX: 50				
Original spacing 4′ x 4′				
10	17	3.3	380	—
15	31	3.8	1,495	—
20	42	4.3	2,746	577
25	50	4.9	3,777	2,980
30	56	5.4	4,531	5,837
35	61	5.9	5,050	8,723

CONTINUED

STAND GROWTH—6
VARIABLE DENSITY YIELD TABLE
Plantations—Southern Appalachians

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
25-YEAR SITE INDEX: 50, CONTINUED				
Original spacing 5′ x 5′				
10	17	3.6	318	—
15	31	4.2	1,327	—
20	42	4.8	2,512	1,327
25	50	5.4	3,516	3,892
30	56	6.0	4,271	6,857
35	61	6.6	4,800	9,815
Original spacing 6′ x 6′				
10	17	3.9	289	—
15	31	4.6	1,245	107
20	42	5.2	2,393	1,884
25	50	5.9	3,383	4,623
30	56	6.5	4,134	7,714
35	61	7.2	4,669	10,758
Original spacing 6′ x 7′				
10	17	4.1	280	—
15	31	4.8	1,219	238
20	42	5.4	2,357	2,110
25	50	6.1	3,341	4,925
30	56	6.7	4,093	8,073
35	61	7.4	4,627	11,164
Original spacing 7′ x 7′				
10	17	4.2	272	—
15	31	4.9	1,197	366
20	42	5.6	2,324	2,342
25	50	6.3	3,305	5,239
30	56	7.0	4,055	8,457
35	61	7.7	4,592	11,592
Original spacing 8′ x 8′				
10	17	4.5	262	—
15	31	5.3	1,167	579
20	42	6.0	2,280	2,731
25	50	6.7	3,255	5,783
30	56	7.4	4,004	9,107
35	61	8.2	4,543	12,323

CONTINUED

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
Original spacing 9′ x 9′				
10	17	4.8	255	—
15	31	5.5	1,147	761
20	42	6.3	2,251	3,071
25	50	7.1	3,223	6,266
30	56	7.8	3,969	9,699
35	61	8.6	4,509	12,989
Original spacing 10′ x 10′				
10	17	5.0	251	—
15	31	5.8	1,133	921
20	42	6.6	2,230	3,377
25	50	7.4	3,197	6,697
30	56	8.2	3,945	10,233
35	61	9.1	4,485	13,585
Original spacing 12′ x 12′				
10	17	5.4	245	50
15	31	6.4	1,115	1,200
20	42	7.2	2,204	3,914
25	50	8.1	3,167	7,454
30	56	9.0	3,914	11,159
35	61	9.9	4,454	14,678
25-YEAR SITE INDEX: 55				
Original spacing 4′ x 4′				
10	19	3.4	474	—
15	34	4.0	1,865	—
20	46	4.5	3,425	1,551
25	55	5.1	4,711	4,980
30	62	5.6	5,652	8,893
35	68	6.2	6,298	12,780
Original spacing 5′ x 5′				
10	19	3.8	397	—
15	34	4.4	1,656	69
20	46	5.0	3,133	2,416
25	55	5.6	4,386	6,030
30	62	6.2	5,327	10,071
35	68	6.9	5,986	14,048

CONTINUED

STAND GROWTH—6
VARIABLE DENSITY YIELD TABLE
Plantations—Southern Appalachians

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
25-YEAR SITE INDEX: 55, CONTINUED				
		Original spacing 6′ x 6′		
10	19	4.1	360	—
15	34	4.8	1,553	467
20	46	5.5	2,985	3,075
25	55	6.1	4,220	6,898
30	62	6.8	5,157	11,092
35	68	7.5	5,822	15,173
		Original spacing 6′ x 7′		
10	19	4.3	349	—
15	34	5.0	1,521	623
20	46	5.6	2,940	3,346
25	55	6.3	4,168	7,261
30	62	7.0	5,105	11,524
35	68	7.7	5,770	15,664
		Original spacing 7′ x 7′		
10	19	4.4	340	—
15	34	5.2	1,493	777
20	46	5.9	2,899	3,625
25	55	6.6	4,123	7,642
30	62	7.3	5,058	11,991
35	68	8.0	5,727	16,186
		Original spacing 8′ x 8′		
10	19	4.7	327	—
15	34	5.5	1,456	1,034
20	46	6.2	2,844	4,097
25	55	7.0	4,061	8,304
30	62	7.7	4,995	12,786
35	68	8.5	5,665	17,078
		Original spacing 9′ x 9′		
10	19	5.0	319	—
15	34	5.8	1,431	1,256
20	46	6.6	2,808	4,513
25	55	7.4	4,019	8,891
30	62	8.2	4,951	13,510
35	68	9.0	5,623	17,896

CONTINUED

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
		Original spacing 10′ x 10′		
10	19	5.2	313	37
15	34	6.1	1,414	1,452
20	46	6.9	2,782	4,888
25	55	7.7	3,988	9,424
30	62	8.6	4,920	14,164
35	68	9.5	5,594	18,633
		Original spacing 12′ x 12′		
10	19	5.7	305	116
15	34	6.6	1,391	1,795
20	46	7.5	2,749	5,549
25	55	8.4	3,951	10,358
30	62	9.3	4,882	15,310
35	68	10.3	5,554	19,980
		25-YEAR SITE INDEX: 60		
		Original spacing 4′ x 4′		
10	20	3.5	580	—
15	37	4.1	2,282	—
20	50	4.7	4,191	2,925
25	60	5.3	5,765	7,637
30	68	5.9	6,915	12,849
35	74	6.4	7,706	17,940
		Original spacing 5′ x 5′		
10	20	3.9	485	—
15	37	4.6	2,026	518
20	50	5.2	3,834	3,896
25	60	5.9	5,368	8,817
30	68	6.5	6,518	14,177
35	74	7.1	7,323	19,374
		Original spacing 6′ x 6′		
10	20	4.3	440	—
15	37	5.0	1,900	978
20	50	5.7	3,653	4,658
25	60	6.4	5,164	9,824
30	68	7.1	6,310	15,369
35	74	7.8	7,124	20,695

CONTINUED

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
25-YEAR SITE INDEX: 60, CONTINUED				
		Original spacing 6′ x 7′		
10	20	4.4	427	—
15	37	5.2	1,861	1,161
20	50	5.9	3,597	4,975
25	60	6.6	5,100	10,250
30	68	7.3	6,246	15,878
35	74	8.1	7,060	21,276
		Original spacing 7′ x 7′		
10	20	4.6	416	—
15	37	5.4	1,827	1,342
20	50	6.1	3,547	5,305
25	60	6.8	5,045	10,701
30	68	7.6	6,189	16,434
35	74	8.4	7,007	21,898
		Original spacing 8′ x 8′		
10	20	4.9	400	—
15	37	5.7	1,782	1,647
20	50	6.5	3,480	5,866
25	60	7.3	4,970	11,493
30	68	8.1	6,111	17,382
35	74	8.9	6,931	22,965
		Original spacing 9′ x 9′		
10	20	5.2	390	56
15	37	6.0	1,751	1,912
20	50	6.9	3,436	6,365
25	60	7.7	4,918	12,196
30	68	8.5	6,058	18,256
35	74	9.4	6,880	23,953
		Original spacing 10′ x 10′		
10	20	5.4	383	112
15	37	6.3	1,729	2,146
20	50	7.2	3,404	6,815
25	60	8.1	4,881	12,840
30	68	8.9	6,020	19,045
35	74	9.8	6,844	24,842

CONTINUED

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
		Original spacing 12′ x 12′		
10	20	5.9	373	207
15	37	6.9	1,702	2,561
20	50	7.8	3,363	7,612
25	60	8.8	4,835	13,970
30	68	9.7	5,973	20,432
35	74	10.7	6,795	26,475
		25-YEAR SITE INDEX: 65		
		Original spacing 4′ x 4′		
10	22	3.7	699	—
15	40	4.3	2,747	418
20	54	4.9	5,045	4,760
25	65	5.5	6,939	11,052
30	73	6.1	8,323	17,860
35	80	6.7	9,277	24,399
		Original spacing 5′ x 5′		
10	22	4.1	584	—
15	40	4.8	2,439	1,148
20	54	5.4	4,615	5,823
25	65	6.1	6,461	12,344
30	73	6.7	7,845	19,322
35	80	7.5	8,817	25,987
		Original spacing 6′ x 6′		
10	22	4.5	530	—
15	40	5.2	2,287	1,668
20	54	5.9	4,397	6,687
25	65	6.6	6,216	13,491
30	73	7.4	7,594	20,682
35	80	8.1	8,576	27,502
		Original spacing 6′ x 7′		
10	22	4.6	514	—
15	40	5.4	2,240	1,877
20	54	6.1	4,330	7,052
25	65	6.9	6,139	13,985
30	73	7.6	7,518	21,276
35	80	8.4	8,500	28,182

CONTINUED

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
25-YEAR SITE INDEX: 65, CONTINUED				
		Original spacing 7′ x 7′		
10	22	4.8	500	—
15	40	5.6	2,199	2,087
20	54	6.4	4,271	7,437
25	65	7.1	6,073	14,509
30	73	7.9	7,449	21,924
35	80	8.7	8,435	28,906
		Original spacing 8′ x 8′		
10	22	5.1	482	73
15	40	6.0	2,144	2,442
20	54	6.8	4,190	8,092
25	65	7.6	5,981	15,435
30	73	8.4	7,355	23,037
35	80	9.3	8,344	30,165
		Original spacing 9′ x 9′		
10	22	5.4	469	150
15	40	6.3	2,108	2,754
20	54	7.1	4,136	8,677
25	65	8.0	5,920	16,268
30	73	8.9	7,291	24,071
35	80	9.8	8,283	31,337
		Original spacing 10′ x 10′		
10	22	5.7	461	216
15	40	6.6	2,082	3,031
20	54	7.5	4,098	9,211
25	65	8.4	5,875	17,030
30	73	9.3	7,246	25,010
35	80	10.3	8,240	32,396
		Original spacing 12′ x 12′		
10	22	6.2	449	328
15	40	7.2	2,048	3,521
20	54	8.2	4,049	10,159
25	65	9.1	5,820	18,376
30	73	10.1	7,190	26,666
35	80	11.2	8,181	34,345

CONTINUED

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
25-YEAR SITE INDEX: 70				
Original spacing 4′ x 4′				
10	24	3.9	830	—
15	43	4.5	3,261	1,195
20	58	5.1	5,991	7,122
25	70	5.7	8,241	15,333
30	79	6.4	9,883	24,021
35	86	7.0	11,015	32,261
Original spacing 5′ x 5′				
10	24	4.3	693	—
15	43	5.0	2,896	1,982
20	58	5.7	5,480	8,258
25	70	6.4	7,674	16,717
30	79	7.0	9,315	25,594
35	86	7.8	10,469	33,984
Original spacing 6′ x 6′				
10	24	4.7	630	—
15	43	5.4	2,715	2,562
20	58	6.2	5,222	9,222
25	70	6.9	7,382	17,999
30	79	7.7	9,018	27,126
35	86	8.4	10,181	35,691
Original spacing 6′ x 7′				
10	24	4.8	610	15
15	43	5.6	2,660	2,799
20	58	6.4	5,142	9,636
25	70	7.1	7,291	18,561
30	79	7.9	8,927	27,804
35	86	8.8	10,093	36,479
Original spacing 7′ x 7′				
10	24	5.0	594	81
15	43	5.8	2,612	3,038
20	58	6.6	5,071	10,073
25	70	7.4	7,213	19,164
30	79	8.2	8,845	28,550
35	86	9.1	10,016	37,317

CONTINUED

STAND GROWTH—6
VARIABLE DENSITY YIELD TABLE
Plantations—Southern Appalachians

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
25-YEAR SITE INDEX: 70, CONTINUED				
		Original spacing 8′ x 8′		
10	24	5.3	572	186
15	43	6.2	2,546	3,445
20	58	7.1	4,975	10,828
25	70	7.9	7,104	20,234
30	79	8.8	8,734	29,842
35	86	9.6	9,908	38,780
		Original spacing 9′ x 9′		
10	24	5.6	557	275
15	43	6.6	2,503	3,806
20	58	7.5	4,911	11,507
25	70	8.3	7,031	21,203
30	79	9.3	8,658	31,047
35	86	10.2	9,836	40,152
		Original spacing 10′ x 10′		
10	24	5.9	547	352
15	43	6.9	2,472	4,128
20	58	7.8	4,866	12,130
25	70	8.8	6,978	22,096
30	79	9.7	8,604	32,145
35	86	10.7	9,784	41,390
		Original spacing 12′ x 12′		
10	24	6.4	534	483
15	43	7.5	2,432	4,702
20	58	8.5	4,807	13,240
25	70	9.5	6,912	23,675
30	79	10.6	8,537	34,091
35	86	11.7	9,714	43,683
		25-YEAR SITE INDEX: 75		
		Original spacing 4′ x 4′		
10	26	4.0	974	—
15	46	4.7	3,828	2,224
20	63	5.3	7,031	10,064
25	75	6.0	9,669	20,582

CONTINUED

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
30	84	6.6	11,601	31,503
35	92	7.3	12,930	41,736
		Original spacing 5′ x 5′		
10	26	4.5	814	—
15	46	5.2	3,399	3,056
20	63	5.9	6,431	11,251
25	75	6.6	9,003	22,026
30	84	7.3	10,935	33,161
35	92	8.1	12,291	43,577
		Original spacing 6′ x 6′		
10	26	4.8	739	68
15	46	5.7	3,187	3,691
20	63	6.4	6,128	12,309
25	75	7.2	8,662	23,441
30	84	8.0	10,585	34,857
35	92	8.8	11,954	45,483
		Original spacing 6′ x 7′		
10	26	5.0	716	143
15	46	5.9	3,122	3,955
20	63	6.7	6,034	12,771
25	75	7.5	8,555	24,072
30	84	8.3	10,479	35,624
35	92	9.1	11,847	46,362
		Original spacing 7′ x 7′		
10	26	5.2	697	217
15	46	6.1	3,066	4,223
20	63	6.9	5,951	13,265
25	75	7.7	8,463	24,753
30	84	8.6	10,382	36,471
35	92	9.5	11,757	47,321
		Original spacing 8′ x 8′		
10	26	5.5	671	336
15	46	6.4	2,989	4,686
20	63	7.4	5,838	14,123
25	75	8.2	8,335	25,975
30	84	9.1	10,252	37,951
35	92	10.1	11,631	49,003

CONTINUED

STAND GROWTH—6
VARIABLE DENSITY YIELD TABLE
Plantations—Southern Appalachians

CONTINUED

Age from seed	Average height of dominants and codominants	D. b. h. of tree of average basal area	Total yield[1]	Merchantable yield[2]
Years	*Feet*	*Inches*	*Cu. ft.*	*Bd. ft.*
25-YEAR SITE INDEX: 75, CONTINUED				
		Original spacing 9′ x 9′		
10	26	5.8	654	437
15	46	6.8	2,938	5,097
20	63	7.8	5,764	14,905
25	75	8.7	8,249	27,088
30	84	9.6	10,163	39,341
35	92	10.6	11,545	50,581
		Original spacing 10′ x 10′		
10	26	6.1	642	525
15	46	7.2	2,902	5,468
20	63	8.2	5,711	15,622
25	75	9.1	8,187	28,118
30	84	10.1	10,100	40,612
35	92	11.1	11,484	52,017
		Original spacing 12′ x 12′		
10	26	6.7	626	676
15	46	7.8	2,855	6,133
20	63	8.9	5,642	16,909
25	75	9.9	8,110	29,952
30	84	11.0	10,021	42,873
35	92	12.2	11,403	54,689

[1] Cubic-foot yield of white pine per acre, including bark, for all trees 3.0 inches d.b.h. and larger to a 3.0 d.i.b. top.

[2] Board-foot yield of white pine per acre to a 6.0-inch top diameter i.b., International ¼-inch rule.

SOURCE: Vimmerstedt, John P. SOUTHERN APPALACHIAN WHITE PINE PLANTATIONS: SITE, VOLUME, AND YIELD. U. S. Forest Serv. Southeast. Forest Expt. Sta., Sta. Paper 149. 13 pp., illus., 1962. *Location:* North Carolina, Tennessee, and Georgia. *Basis:* 112 plots in 78 plantations that were unburned, unthinned, and free of large openings or significant numbers of trees of other species. *Reliability:* The regression equations upon which the estimate of cubic-foot yield, average d.b.h. and board-foot yield are based accounted for 90 percent, 93 percent and 95 percent of the total variation in the data, respectively.

(Net annual volume growth per acre, [1] in board feet)

Current gross volume per acre[1] (M bd. ft.)	No. of trees per acre in the 7.6 to 8.5-inch d.b.h. class						
	5	10	20	40	60	80	100
REGION B, SITE I[2]							
1.0	102	120	174	305	407	485	531
2.0	166	185	238	369	472	550	595
3.0	223	241	294	425	528	606	651
4.0	272	291	344	475	578	656	701
6.0	332	351	404	535	638	715	761
8.0	403	422	475	606	709	786	832
10.0	441	460	514	644	748	824	860
15.0	550	569	623	753	857	933	969
20.0	585	602	655	786	890	968	1,013
25.0	640	657	710	841	945	1,023	1,068
30.0	680	697	750	881	985	1,063	1,108
40.0	717	734	787	918	1,022	1,200	1,145
50.0	726	743	796	927	1,031	1,209	1,154
REGION B, SITE II[2]							
1.0	90	117	173	208	274	332	368
2.0	149	167	201	286	334	390	427
3.0	201	219	253	338	386	442	479
4.0	223	240	274	340	406	464	500
6.0	303	320	354	420	486	544	580
8.0	381	398	432	498	564	622	658
10.0	430	447	481	548	613	671	707
15.0	470	487	521	588	653	711	747
20.0	535	554	587	654	720	776	814
25.0	439	458	491	558	624	680	618
REGION C, SITE I[2]							
1.0	131	149	201	329	429	505	550
2.0	194	212	264	392	492	568	613
3.0	248	266	318	446	546	632	667
4.0	294	312	365	492	593	669	714
6.0	353	371	424	551	652	728	773
8.0	427	445	498	625	726	802	847
10.0	475	493	545	673	774	850	895
15.0	627	645	697	725	826	1,002	1,047
20.0	707	725	777	805	906	1,082	1,127

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STAND GROWTH—7
STAND PROJECTION GROWTH ESTIMATES
Natural Stands—New York

CONTINUED

Current gross volume per acre[1] (M bd. ft.)	No. of trees per acre in the 7.6 to 8.5-inch d.b.h. class						
	5	10	20	40	60	80	100
25.0	791	809	861	989	1,135	1,165	1,191
30.0	850	868	920	1,048	1,194	1,224	1,250
40.0	869	886	938	1,066	1,212	1,242	1,268
50.0	828	846	898	1,026	1,172	1,202	1,228
REGION C, SITE II[2]							
1.0	86	102	145	238	303	343	366
2.0	139	155	198	291	356	396	419
3.0	186	202	245	338	404	443	466
4.0	229	245	288	380	446	486	509
6.0	278	294	337	429	495	535	558
8.0	349	364	407	500	565	605	627
10.0	399	415	458	550	616	656	678
15.0	515	530	574	666	731	771	793
20.0	488	504	547	639	705	745	767
25.0	414	430	473	565	631	671	693

[1] Both current gross volume and net annual growth per acre are in terms of the International ¼-inch log rule and assume a 1-foot stump and a 6-inch diameter top inside bark. Current gross volume includes all volume within merchantability limits on live trees 8.6 inches or more in d.b.h. Net annual growth is made up of an estimate of accretion based on current gross volume, plus an estimate of ingrowth based on the number of trees in 7.6 to 8.5-inch d.b.h. class, minus an estimate of mortality and cull percent based on current gross volume.

[2] Region B is that part of northern New York characterized by a growing season of 105 to 134 days and soils of very low productivity. This region centers on Hamilton County and includes parts of surrounding counties as well. Region C comprises areas in Northern New York with a growing season of 135-159 days and with soils of low productivity. Region C extends in a band to the north, east, and south of region B.

Site is classified on the basis of average d.b.h./merchantable height relation among dominant and codominant pines. Merchantable height is measured to a 4-inch top diameter inside bark. The following tabulation provides the basis for site classification:

Average d.b.h. of dominant and codominant pines (inches)	*Average merchantable height*	
	Site I (feet)	*Site II (feet)*
6	19	16
8	35	30
10	49	41
12	58	47
14	64	51
16	69	53
18	73	55
20	76	56
22	78	57
24	80	—
26	81	—

SOURCE: Ferree, Miles J., and Robert K. Hagar. TIMBER GROWTH RATES FOR NATURAL FOREST STANDS IN NEW YORK STATE. N. Y. State Univ. Coll. Forestry Tech. Pub. 78. 56 pp., illus., 1956. Syracuse. *Location:* Northern New York. *Basis:* 63 one-fifth acre plots. *Reliability:* Estimates based on 10 or more ⅕ acre plots in relatively homogeneous stands will usually be subject to standard errors of less than 10 percent, if current gross volume and number of ingrowth trees on these sample plots are typical for the stand.

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